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VII.

AN EXPOSITION OF THE MODE IN WHICH WATER IS AFFECTED BY A BODY MOVING IN IT.

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In the discussion of the "Progressive Trials of the Steam Barge of the Commandant of the New York Navy Yard", a report made by the writer and printed in the first issue of the "Journal of the American Society of Naval Engineers", exceptions were taken to his explanation of some of the phenomena attending the passage of a vessel through water. In the report referred to, these explanations were carried no further than necessary to show how the results of those "Trials" were due to and influenced by the mode of action of the water under the experimental conditions; but the writer, in view of the objections advanced during the discussion, believes that some good can be accomplished by a more extended exposition of his observations on this subject, and he therefore submits the following to be considered by the reader in connection with the report and discussion above referred to. The subject is purely experimental, it is

neither theoretical nor abstract, and the truth depends on careful observations made during a sufficient length of time and under sufficiently varied conditions to ensure accuracy, and on the requisite sagacity to detect during all the apparent variations of the phenomena, the causative principle or system of action to which they are due.

Passed Assistant Engineer Mattice thinks that the writer should not attribute the "squatting", or change of trim which a vessel experiences when its speed surpasses a certain speed (variable for each vessel), solely to the cavity at the stern caused by the forward motion of the vessel not being filled with sufficient rapidity by the inflowing water; and his reason is "*that a vessel might be made with an after body of sufficient length and of proper form to allow the cavity to be filled with sufficient rapidity, but squatting might still result from the hollow of the bow or displacement wave occurring somewhere along the after part of the vessel. When the hollow of the bow wave coincides with the hollow caused by a full after body the squatting will be a maximum.*"

The answer to this is that in a screw steamer there is no such sufficient wave flowing along the side of the vessel, caused by the displacement at the bow, as he imagines. The undulations due to this cause are exceedingly small, and produce no sensible effect in lowering the water surface at the vessel's stern. Any lowering that appears there is caused by deficiency of water due solely to the cavity formed by the advancing vessel not being filled with the inflowing water. This depression may be mistakenly assigned to a hollow caused by a bow wave, but a comparison between the shallowness of the undulations along the side of the vessel with the depth of the stern depression will at once show the error; besides, the depression at the stern is between the extended sides and in the immediate wake of the vessel, while the hollows of the bow undulations are exterior to the extended sides of the vessel and are not in its wake, and are not connected with the stern depression either in position or magnitude. The facts just stated will become very clear if the undulations caused by the wheels of a paddle-wheel steamer be observed. These waves are quite high at the after part of the

wheels where they are generated, and rapidly diminish in height as they pass towards the stern, becoming comparatively quite small there, but they never pass into the wake of the vessel, which remains smooth and flat; they continue on separately and exterior to the extended sides of the vessel until they merge into the mass of level water a long distance abaft the stern. I wish particularly to emphasize the fact that the waves generated at the sides of the vessel by the paddle wheels never pass into the wake of the vessel or cause depressions there. Now, if the large waves caused at the vessel's sides by these wheels do not appreciably affect the water level in the wake at the vessel's stern, how much less will the comparatively very small bow waves do it? Did the hollows of the bow waves cause any sensible depression of the water at the vessel's stern and thus produce "squatting", then all vessels ought to "squat" at all speeds—low as well as high—for these waves exist for all vessels and at all speeds. Now observation shows that within certain limits of speed (variable for each vessel) there is no "squatting", and observation also shows that the speed at which "squatting" begins is greater and greater as the vessel is longer and longer; indeed, the length of the vessel appears to be, if not the only factor, certainly the principal one, in determining the speed at which "squatting" commences, and this should be the fact if squatting be due wholly to the incompletely filled cavity of the stern by the ascending water from the horizontal plane of the rabbet of the keel. These statements are strictly conformable to the closest practical observations, and the more sagaciously such observations are made the more confirmed will these facts be.

The form of the bow for equal length of fore body and within the limits of practice, has very slight influence on the resistance, and none at all on the squatting, though the magnitude and position of the bow waves generated must be considerably affected thereby, whether the principal part of the lines of that form be straight, or concave, or convex. The exigencies of the construction require that the lines from the rabbet of the keel upwards to a certain distance should be hollow in order to obtain a uniformly or gradually warped surface for the side of the

vessel. The influence of even very considerable variations of these lines is purely imaginary, and no experiments can be cited to prove anything in this relation. The differences of opinion are mere notions. The few experiments—very few—which have been made, have failed to show any difference in the resistance of the V and U bows of equal lengths attached to otherwise the same vessel, much less can any difference be maintained for slight variations of the inflections of the lines of the same kind of bow.

Before mathematics can be applied to a physical problem, the physics of that problem must be mastered, which can only be done by experiment. The mass of equations that have been invented by professors, from the days of Newton to the present hour, on unfounded assumptions of how water should, could, would, or might act in relation to the passage through it of ship-formed solids, including what is called the wave theory, may be dismissed as being mostly mere rubbish. The water is displaced vertically at the bows of vessels and is thence spread out by gravity over the general water level in a direction at right angles to the surface of the bows, because the water, being practically incompressible, cannot be forced into other water, and must rise consequently into the easily compressible atmosphere as the only place where it can go. The immersion of a vessel into the ocean raises the level of the ocean, and the forward movement of the vessel is only a continuous immersion of it, producing the same result.

The water is replaced vertically in the cavity left at the stern by the advance of the vessel, and by different water from that displaced at the bow, the replacement being simultaneous with the displacement. The water rises into the cavity necessarily from the locality of greatest pressure, which is undoubtedly that of the horizontal plane of the lower edge of the rabbet of the keel. The writer has never been able to observe any sideway flow into the cavity, not even on the surface of the water where it would appear, if anywhere. The race from the paddles of a paddle-wheel steamer shows like a riband with sharply defined parallel edges, owing to its surface being uniformly covered with

white foam. The riband continues in an unbroken straight line long abaft the stern of the vessel, without showing the least tendency to flow in around the stern, leaving the wake of the vessel unaffected and clear. The two races, one on each side of the vessel, are so far from being able to unite by any side flow of water to fill the cavity after they reach the stern, that they are really kept apart by the mass of water rising vertically between them to replace the water displaced by the bow, which mass of water by virtue of its *vis viva* ascends above the general water level and effectually separates the races for a considerable length. The only side flow of water there is, is outwards from the wake of the vessel to the race of the wheels, and not inwards from the race to the wake, and this side flow is only on the surface, and is due to the elevation of the wake water by its greater *vis viva* above the race water. The well marked phenomena of the paddle-wheel race not only gives no evidence of either a cross-flowing current or of a following current, but furnishes the most indubitable proof to the contrary.

The water displaced by the paddles and forming the slip is supplied vertically from beneath and is raised vertically—not moved horizontally by them—and spreads out by gravity over the general water surface. Its *vis viva* is, of course, greatly less than that of the water filling the cavity at the stern of the vessel. There is no current or bodily horizontal movement of water having the depth from the water level to the lower edge of the deepest immersed paddle, there is only the slight surface current due to the outflow over the general water level of the water raised by the paddles. The current does not extend below the general water level. Opinions must not be formed by observing merely surface phenomena, the depth must be ascertained to which these phenomena extend.

Mr. Mattice disagrees with the writer as to the non-existence of a following wave, and gives as a reason the fact "*sometimes seen of a boat being towed behind a bluff stern vessel with a slack tow rope; that is to say, the boat is carried along by the eddying water following the vessel, with little or no pull on the tow rope.*" This fact can be seen just as often in the case of sharp sterned

vessels as of bluff sterned ones. It occurs only at a certain speed of vessel (a very low one of two or three miles an hour), and with the boat in a particular place, and the explanation is as follows: When the ascending column or mass of water which replaces at the stern the water displaced at the bow, reaches, in ascending, the general surface of the water, it rises above the same to a certain elevation by reason of its *vis viva*, and as a result of this elevation it flows by gravity over the general level in all directions as from a center, and consequently this slight surface current flows towards the vessel. Now, if the speed and other conditions of the vessel be such as to allow the rising mass of water to reach the surface just sufficiently abaft the stern to accommodate the length of the boat between it and the stern, the boat will be in this slight surface current and partake its movement towards the vessel, but it must be recollected that this current is wholly above the general level of the water, and not at all beneath; it cannot under any circumstances affect the action of a submerged propeller at the stern, and as the vessel increases its speed, the rising mass of water meets the general water level farther and farther abaft the stern, because as the time of its rising is constant, being wholly due to gravity and unaffected by the speed of the vessel, the greater that speed the greater will be the distance between the stern and the capital of the ascending mass of water. Moreover, there is a considerable pull through even the slack rope by which the boat is towed; an infinite power would be required to straighten the rope to a mathematical line, and the slackness will be in some ratio of the weight of the rope to the resistance of the boat. Now the resistance of a small, unloaded boat at a very low speed is not great compared with the weight of its tow rope, and considerable force can be transmitted from the vessel to the boat through what appears to be a very slack rope. The case is easily tested by placing the small boat in the perfectly still water of a basin at a distance from the shore equal to the length of the rope, one end of which is fastened to the shore, when the boat will be seen to very promptly move towards the shore by the weight of the slackening rope and without the assistance of any current, until boat and shore meet. If

the shore continuously recedes, as in the case of the slowly advancing vessel, the boat would continuously approach the latter by the pull of the weight of the rope, but the amount of slackness would remain constant.

The same phenomena in the displacement of water are observable in the case of the screw propeller working with slip, and are most marked when the screw is worked with the vessel secured stationary to the dock, in which case the slip is a maximum. The water displaced by the screw rises vertically to the surface as soon as it is freed from the constraints of the hull and of the screw blades, and above the surface to the height due to its *vis viva*. The capital of the rising water column can be very plainly seen a short distance abaft the stern of the vessel, and the surface currents flowing from it in all directions as from a centre are also plainly visible, and if chips or other light floating bodies are present in abundance, they will be found to indicate the directions of this surface current exactly, some of them will return in a straight line from the capital of the water column back to the screw, others will float off in the exactly opposite direction, while still others will drift away in right-angled directions to the keel of the vessel. These currents, however, are only above the surface of the general water level, and do not affect the water beneath that surface.

The same phenomena of "squatting" also exist in the case of a vessel secured stationary at the dock in sufficiently deep water while the screw is working, as in the case of the vessel propelled in free route by the screw. So long as the water gets "solidly" upon the entire surface of the screw blades no squatting is apparent at the dock, but as soon as this supply of water (by gravity from beneath the screw) becomes insufficient, the vessel begins to squat, and after this effect commences, the more rapidly the screw is revolved the deeper will be the squatting. Furthermore, up to the speed of the screw at which squatting commences, the number of revolutions made by the screw per unit of time will be in the ratio of the square roots of the net pressures (not indicated pressures) upon the steam pistons, but after squatting begins, the net pressures on the pistons will be in a less ratio than

the squares of the revolutions of the screw per unit of time, and less as the squatting is greater. Now the deficiency of water at the stern which this squatting indicates is not caused by any wave or current or undulation of any kind from the bow towards the stern, because chips or other floating objects will show (if there be a proper depth of water beneath the vessel's keel) a current in exactly the opposite direction, that is, one proceeding along the vessel's side from the stern towards the bow. Of course, the water deficiency at the stern is caused by the fact that the screw is able to displace the water faster above than it can be supplied from below. As long as there is a sufficient depth of water beneath the screw, that supply will come in a vertical column, the current along the vessel's side from stern towards bow, proving that no water is received sideway or horizontally. If, however, the depth of water beneath the vessel is insufficient to furnish a full supply from beneath, then there will be a flow of water from the sides or horizontally to make good the deficiency, in which case there will be a current more or less strong from the bow towards the stern, and this is exactly what takes place in a very marked degree when the vessel is screw propelled in shallow water. Then most of the water filling the cavity behind the stern comes from the sides, horizontally, not from the bottom vertically; as long, however, as sufficient water can be had from below none comes from the sides.

The action of the slip of the screw when the vessel is in free route, assists in depleting the water at the stern of the vessel, causing thereby more squatting than otherwise would be, and is one of the principal agencies, taken in conjunction with the obliquity of the screw's axis to the horizontal, that makes the screw inferior in more or less degree to the paddle-wheel in economical efficiency, and particularly when propelling against head winds and seas, in which case the slip of the screw, and the effect of that slip in lessening the water supporting the after body of the hull, are maximum.

Mr. Mattice states further: "*Another point on which I cannot agree with the author is the theory that the water displaced by the slip of the screw rises vertically instead of flowing horizontally.*"

There is certainly a necessity in this connection for Mr. Mattice to show where or into what his horizontally flowing water flows; if it flows it must flow somewhere, and it certainly can not flow into space already occupied by other water, because of the incompressibility of water; it must, therefore, rise into the elastic atmosphere, because other place for it there is absolutely none. Yet the irresistible force of this argument is ignored, and no attempt to meet it made; mere dissent without sufficient proof is not argument. Mr. Mattice continues: "*Towards the surface is undoubtedly the direction of least resistance, but the water is set in motion, or rather is acted on by a force, in practically a horizontal direction, and it must move in that direction unless acted upon by external forces.*"

A universal law of mechanics is that a pressure will move in the direction of least resistance, and if, as Mr. Mattice above admits, that direction is undoubtedly towards the surface, the water yielding to the pressure of the screw *must* take that direction, *i. e.*, rise vertically, and there remains for Mr. Mattice to show how or in what manner the slip of a screw is an exception to a universal mechanical law as well fixed as that of gravity. Mr. Mattice, as quoted above, in relation to the slip of the screw, says: "*The water is set in motion or rather acted on by a force, in practically a horizontal direction, and it must move in that direction unless acted upon by external forces.*" It is acted upon by external forces, namely, the resistance furnished by the inertia and incompressibility of the surrounding water; these constrain it to the vertical direction, without their opposition the direction would undoubtedly be horizontal. Mr. Mattice seems to have some confused idea of this as he continues: "*An external force exists in the difference of pressure of the surrounding water in various directions. The resultant of these pressures tends to force the moving particle of water upwards, and it will, therefore take a direction resultant upon the forces acting on it, or an obliquely upward direction.*" An obliquely upward direction in this matter is a vertical direction, and this final conclusion of Mr. Mattice's is in absolute opposition to the statement with which he commenced, namely, that he could not agree with the author in the theory that the

water displaced by the slip of the screw rises vertically instead of flowing horizontally.

Mr. Mattice concludes with the following remark: "*In the case of the moving particle of water the tendency to rise exists only as long as the motion imparted by the propelling instrument exists, so that when the motion is destroyed by fluid friction the vertical motion ceases, and it is doubtful if more than a very small portion of the water ever reaches the surface.*"

Here, again, is the admission of the vertical movement of the water displaced by the screw, coupled with a notion that this movement does not reach the surface because the fluid friction may destroy it.

When the two facts are considered that the entire space below the general water level is filled with incompressible water, so that any movement of any part of this water below the water level is constrained to be in the vertical direction, that is, into the atmosphere, as the sole place where it can go, and that the water displaced by the screw below the water level has a constant bulk because of its incompressibility, nothing can be more obvious than that the whole of this displaced bulk must be raised to the surface with the velocity of its displacement, the *vis viva* due to which carries it above the surface and produces an elevation or wave at the place where it meets the surface, after which the water thus lifted spreads out by gravity over the surface, producing a shallow surface current. The elevation alluded to can be seen in a very marked degree in the case of any screw vessel secured to the dock while its screw is working. The whole of the slip water reaches the surface in exactly the same manner and for the same reason that the whole of the displacement of a vessel is lifted to the surface and above it by the fore body. As for the vertical movement of the slip water imparted by the screw ceasing before it reaches the surface because of fluid friction, such a result is impossible owing to the fact that the action of the screw is continuous—not intermittent—and that its pressure upon the slip water never ceases or varies until that water has reached the surface.

While on this subject an additional cause may be given for the

greater economic efficiency of the paddle-wheel over the screw as a propeller against head winds and seas: it is, that under such conditions, and as ordinarily proportioned to the vessel—particularly to seagoing vessels—the *propelling surface* of the paddle increases while the propelling surface of the screw diminishes, meaning in both cases not the nominal surface, but the portion of that surface in actual propulsive action horizontally. The paddles in seagoing vessels are so much immersed relatively to their surface and normal slip that the "rolling circle" dips very considerably beneath the surface of the water. The "rolling circle" is the circle concentric with the paddle-wheel, whose circumference multiplied by the number of revolutions made by the paddle-wheel per unit of time equals the speed of the vessel during the same time. When the "rolling circle" dips beneath the surface of the water, none of the paddle surface between the lower horizontal tangent of that circle and the water surface acts propulsively, but, on the contrary, it acts retardatively, because the portion of the paddle surface lying between these limits pushes before it a corresponding mass of water with a velocity equal to the difference between the velocity of the vessel and the mean horizontal velocity of the retarding paddle surface. For all cases, therefore, where the "rolling circle" dips beneath the water surface, the paddle surface comprised between the surface of the water and the lower horizontal tangent of the circle is an addition to the resistance to be overcome by the paddle surface lying below that tangent. Now the effect of head winds and head seas is to increase the slip of the paddles, and, as a consequence of such increase, to diminish the diameter of the "rolling circle," each increase of slip not only brings into propulsive action the portion of the paddle surface between the lower horizontal tangents of the circle as it was and as it is, but removes the retarding effect of that portion, so that the gain is twofold, and there arises, simultaneously with the increased resistance of the vessel due to head winds and seas, both increased paddle surface to overcome that increased resistance and decreased retarding paddle surface; hence, the increased slip of the paddles with increased vessel resistance is by no means as great as it

would be, without the additional surface brought into propelling action and removed from retarding action.

Of course, if the paddle surface were originally so proportioned to the vessel resistance that, under normal conditions, the lower horizontal tangent of the "rolling circle" was at or above the water surface, there would not be the effects just described. In practice, however, this is rarely the case even with river paddle-wheel steamers, and never with seagoing ones, because, with the proportions imposed by practice, the sum of the losses by slip and by the water pushed forward by that portion of the paddle surface which lies between the water surface and the lower horizontal tangent of the "rolling circle" is less than the loss by slip alone when this tangent is kept at or above the water surface. The most economical proportions for the paddle-wheel as regards the power alone, are the greatest possible diameter, the greatest possible length of paddle, and the least possible immersion of the paddles, reducing the slip as nearly as possible to zero, but such proportions involve too great losses in other respects, and too great inconveniences, to be adopted in practice.

No matter what the trim of the vessel may be, the push of the paddle-wheel shaft is always horizontal, and nothing is lost by obliquity of application of the power to the vessel.

The water put in motion by the slip of the paddle-wheel, is raised vertically above the general water level over which it flows out by gravity. The large wave at the place where the paddles leave the water is thus formed—a small and but a very small portion of that wave being due to water lifted bodily by the emerging radial paddles. The current from the paddle-wheel is simply a surface current due to this spreading out over the general water level by gravity of the water raised above that level by the slip of the paddles. The water of the succeeding undulations caused by the wave in question has no progressive movement. The same wave will be found at the emerging paddles in the case of vertical paddles which have no bodily lifting effect upon the water as well as in the case of radial paddles. The water displaced by the slipping paddles

obeys exactly the same laws as the water displaced by the fore body of the vessel.

The loss by the resistance of the wetted surface of the paddles, is nearly insignificant on account of their very slow movement in descending from the surface of the water to their lowest position and then in returning thence to the surface of the water. The portion of the rings of the paddle-wheels which lie beneath the water surface have a surface resistance proportional to their wetted area and to the square of their circumferential velocity. This resistance, however, assists the propulsion, and, indeed, a vessel may be propelled by vertical discs immersed less than their radius, and revolved in the proper direction.

The loss of useful effect by the oblique action of the paddles upon the water, is all measured in their slip; the greater the obliquity of the paddles to the water surface, other things equal, the greater will be their slip for equal paddle surface and diameter of the centre of pressure of the paddles.

The above remarks are, of course, for the ordinary or radial paddle-wheel. By the employment of proper mechanism, the paddles can be made to remain nearly vertical during their trajectory through the water, and their slip will be proportionally lessened in consequence, the same paddles being employed as in the case of their being used radially; but the loss by the friction of this mechanism is probably greater than the gain by the lessened slip of the paddles unless the obliquity of the latter were excessive. The great inconvenience, however, of such mechanism, and the impossibility of preventing rapid and excessive wear of its journals, or of keying up and adjusting them while in operation, in consequence of which the concussion and noise soon becomes unendurable, will ever prevent the use of the vertical paddle, except in very special and rare cases.

In the case of the screw propelling against head winds and seas, there is not only no increase possible of the propelling surface, but always a more or less decrease of that surface, due to the pitching of the vessel. The more the vessel pitches the greater is the inclination of the screw axis to the horizontal and the less proportionally is the propelling surface in the hori-

zontal direction. The thrust of the screw being more obliquely applied to the vessel, the slip is correspondingly exaggerated and a less fraction of the engine power is utilized propulsively. Now the water which supplies the screw ascends vertically into the cavity at the stern formed by the vessel's advance. When the stern ascends in pitching, it is going directly away from this ascending column of water, and the screw has to that extent no water to react on, although it may have normal immersion enough to be entirely below the general water level, while no additional benefit is derived when the stern is descending and consequently meeting the ascending mass of water. Of course, the pitching may be so violent, and the normal immersion so small, as to throw a considerable portion of the screw entirely above the general water level for a time. Thus the stronger the head winds and the higher the head seas, whereby the resistance of the vessel is abnormally more and more increased, requiring the screw surface to be correspondingly more and more increased, it is more and more decreased, becoming in this respect exactly the opposite of the paddle-wheel whose paddles under the same conditions receive a greater and greater accession of propelling surface. The difference between the efficiency of the screw and paddle-wheel under these circumstances is more marked in the case of short vessels than of long ones, because short vessels pitch through a greater angle than long vessels, other things the same.

In the case of the screw vessel being driven at a speed greater than that at which "squatting" commences, the same increased inclination of the axis to the horizontal takes place as in pitching, with the same losses of useful effect and increase of slip above the normal, disadvantages which, under similar conditions are not experienced by the paddle-wheel.

To return to the phenomena of water movement in relation to the passage of a body through it. The most instructive experiment, often made by the writer, is to take a piece of ordinary thin board, or of boiler plate, about 12 inches wide and of convenient length, and then from the side of a screw launch going at the rate of about three miles per hour, immerse the

board or plate vertically to a depth of, say, 18 or 24 inches, and at a distance of about two feet from the side of the launch. On the front of the board the water will rise vertically to a height due to the velocity of the launch, and will then spread out by gravity over the general water level forward of and at right angles to the board. Behind the board will appear a sharply defined cavity extending down to the bottom edge of the board, from which edge the water will be seen to rise in a reversed curve until it meets the general water surface, the shape of this curve forming the bottom of the cavity, is something like the sign $\int$ of integration, but the two sides of the cavity are absolutely vertical from top to bottom, no side flow of water from them entering the cavity which is wholly filled from beneath vertically. The deeper the board is immersed the more strongly marked become these appearances, and there is not the faintest indication of any following current. The curve of the bottom of the cavity is exactly the proper form for the after body of a vessel moving at the speed of the board; that is to say, the vertical sections of the after body of such a vessel should have such a curve.

What happens in the case of the board happens also in the case of a vessel, though the appearances are there masked by the tapering fore and after bodies attached to the greatest immersed transverse section of the hull. The water is displaced vertically by the fore body, and replaces itself vertically along the length of the after body; and the immersed solids of all vessels are really modeled on these conditions of displacement and replacement. The elementary model of all ship-formed bodies is made from a parallelopipedon by cutting off two equal triangular prisms at the bow by vertical planes, forming thus a U-shaped bow; and by cutting off one triangular prism at the stern by a plane inclined to the horizon and moving crosswise the parallelopipedon, forming thus a bateau stern. All that modeling does in addition to these cuts consists in adapting the form to the necessities of the construction, rounding off the angles, beveling the planes, changing from one plane to another

by gradually inflected curves, balancing the fore and after bodies in connection with the weights to be carried, so as to obtain the desired trim, making the displacement at a given draught of water equal to the sum of the weight of the hull and of the weights to be carried, adapting the proportions of length, breadth and draught of water and of fullness or leanness of model to the particular service for which the vessel is to be employed, to the speed desired, and to the kind of propelling means used; curving inboard the sides of the vessel along the central portion a proper distance upward from the water surface, so as to make, when the vessel rolls, the solids of immersion and emersion on opposite sides equal, and thus prevent a lifting motion of the vessel bodily when it rolls. These are all matters of mere common sense, and do not require any mathematics beyond simple arithmetic. All the calculations involved, such as of displacement, areas of sections, wetted surface, are mere approximate measurements of irregular figures to which the higher mathematics can not be applied; and as regards the calculations of stability, inasmuch as they involve a knowledge of the position of the centre of gravity of the loaded vessel, which position is unknown and only arbitrarily assumed, such calculations seem very much like an absurd waste of time; as the result is founded on guesswork, it might as well be guessed at first without expending the work.

The celebrated models of the great French naval architect, Sanè, made for different classes of sailing vessels for the French Navy, such as line-of-battle ships, frigates and corvettes, and adapted for the distribution of weights, sail power, etc., required for the purposes of war vessels previous to the era of steam navigation and modern artillery, were made entirely tentatively, and were purely experimental results gradually arrived at. Sanè's great merit was that having unequaled opportunities for experimenting on the grand scale, he experimented to the utmost, accurately observing physical phenomena as connected with his profession, and sagaciously applying his observations to practice. Mathematical science had really no part in his work, and as he allowed nature to determine his models they remain to this day as appropriate as when he formed them.

A vessel is a partly immersed solid, and the laws of fluid resistance applicable to that case vary from the laws applicable when the solid is wholly immersed. If, in the latter case, the solid be spindle-formed with ends properly tapering for the speed with which it is moved through the water, the only resistance experienced from the water will be that due to the wetted surface of the solid. Whatever power was expended by the fore body in displacement of water is recovered by the closing in action of the replacement on the after body. The displaced water fills the cavity at the stern with the same pressure required to displace it, so that there is no lifting of water above the surface, or vertical movement of the centre of gravity of the displaced water; there is simply transference of pressure and of water from the fore body to the after body through the medium of the intervening water.

In a similar manner, a properly shaped after body for a given speed of vessel, enables a considerable portion of the power expended by the fore body in displacing water to be recovered by the after body, the vertically ascending mass of water filling the cavity due to the advance of the vessel acting by its pressure and by its *vis viva* propulsively on the inclined overhanging surface of the after body.

In the case of a solid exposed to a rapidly flowing current of water, and resting on the bottom of the stream, like the pier of a bridge, there is indeed a very strongly marked "following current", because there is no possibility of the space behind the pier or in its wake being filled with water ascending vertically from beneath. The current between the extended parallel sides of two adjacent piers, retains its form and velocity for a considerable distance after passing the lower ends of the piers, that is to say, the current after passing these ends has its sides still vertical from top to bottom; there is no sideway flow around the lower ends of the piers, as may be proven by floating objects, such as chips thrown into the stream midway the length of the piers and close to their sides, and which pass on in the straight lines of the extended sides of the piers for a considerable distance without the slightest deflection. The water race between the piers re-

tains its form after clearing them for a considerable distance, while in the wake of a pier, between two water races, there is a well marked return current commencing at a considerable distance below the pier and advancing straight up to the lower end of the pier, where the principal portion of it descends vertically to nearly the bottom with much velocity. This return water is carried or dragged away by its cohesion with the water of the vertical walls of the race from between the piers, the descending return current supplying the water beneath. The water between the piers moves *en masse* for its entire depth, as it passes from a higher to a lower level: the return current is due to the backward water pressure existing a considerable distance below the piers, where the current by widening has lost a large portion of the velocity it had acquired in the contracted space between the piers.

This subject was extensively experimented with by the writer many years ago at the bridges over the Seine in Paris, on the occasion of an extremely high inundation of that river. The narrowness of the bridge spans, and the great velocity of the water through them, caused the phenomena to be strongly and unmistakably marked.

An understanding of the mode of movement of water when pressed by solid bodies moving freely in it, is necessary for the avoidance of many errors as regards the phenomena of ship propulsion, and especially in relation to the slip of the propelling instruments. Most obviously, the thing pushed cannot go faster than that which directly pushes it, even in the hypothetical case of an unyielding fulcrum, much less in the actual case of a receding, highly mobile fulcrum like water, yet in the case of the screw propeller there seems a belief in many minds that by means of a following current induced by the forward movement of the vessel itself, there may be an apparent negative slip of the screw as regards the speed of the vessel through the water considered at rest, while this slip as regards an assumed following current, may be positive. Negative slip means that the speed of the vessel through the water is greater than the speed of the form of the screw which propels the vessel; that is to say, the product of

the number of revolutions made by the screw in a given time into its pitch is less than the speed of the vessel during the same time. The whole notion of negative slip rests on the completely baseless supposition that the cavity at the stern caused by the advance of the vessel, is filled by water flowing in from aft—not from crosswise the vessel—and acting upon the screw but not upon the vessel, thereby increasing in some unexplained and unintelligible manner the propelling efficiency of the former. But why should the water be supposed to flow into the cavity from aft alone, and not simultaneously from each side? Indeed, if the cavity is to be filled by any *horizontal* inflow, the filling would be preferably from the sides, because they are nearer to the stern of the vessel than the after part of the cavity; in which case there would be two opposing currents striking the screw from each side, but incapable, either singly or combined, of producing the slightest effect upon its propelling efficiency. Let the supposition be made, however, that the cavity is filled wholly by a current from aft. Evidently, if such a current exist, it will act just as efficiently against the stern of the vessel, as against the screw, so that the mutual relations of the two will be unchanged, and the screw will receive no increase of propelling efficiency.

This argument has been either ignored or its force not comprehended, for it utterly disposes of the notion of negative slip, even if a following current be allowed, because no such current can exist and not act on the vessel in free route with the same force as on the screw.

When the vessel is secured to the dock in a swift current, the pressure of the current upon the vessel and upon the screw is measured by the strain upon the securing ropes, and if a dynamometer be fitted to the screw shaft—supposed to have endwise play—the screw, though motionless, will produce a thrust upon the dynamometer, and consequently upon the vessel, corresponding with the pressure of the current upon its blades. If the following current were sufficiently strong, the screw would rotate by the pressure of the current upon the oblique surfaces of its blades. But, evidently, if the vessel be free and drifts in the current with the screw motionless, then the dynamometer would not

show any pressure, for the vessel would recede as fast as the screw shaft could advance. In order that a following current may increase the pushing efficiency or thrust of a screw, the vessel must be stationary, in which case the full pressure of the current upon the screw blades would be transferred as pressure or thrust upon the vessel. The thrust of the screw for a given number of revolutions per minute is just the same when the vessel is steaming with the current as when it is steaming against the current, and the piston pressure to make these revolutions is just the same (neglecting the effect of the inclined surface of the current), consequently the effect upon the propelling efficiency of the screw by a current is *nil.*

Before quitting this subject it may be useful to inquire regarding any evidence by practical experiment of the existence of negative slip.

In the case of a vessel propelled by a screw of exceedingly great acting surface proportionally to the resistance of the vessel, and therefore having only a very small positive slip, that slip may be made to appear negative by a slight error increasing the speed of the vessel, or by an error in the pitch of the screw decreasing the pitch; or by a combination of the two errors a considerable amount of negative slip might be made to appear when in reality there was a small positive slip. Now, to exactly determine the speed of a vessel is very difficult, especially in a varying tideway, and an error of several per centum is easily made even with great care, unless the mean of a great many more runs over a measured base than are usually made is taken. Then there is no certainty that the pitch of any screw is the intended pitch, unless the pitch is accurately measured from the casting, which is scarcely ever done—being laborious and expensive with large screws—so that chances of error from this source always exist. In view of these facts it is not at all surprising that cases of apparent negative slip can be produced, but it is well worthy of remark that these cases are found in only the Admiralty reports of the speed and power trials of British war steamers, and *nowhere else.* This phenomenon has never occurred with any merchant steamer of any nationality, nor in any war steamer of the French

or American navies, and not often in those of the British navy. Now, how reliable are the Admiralty reports? The speed and other efficiency of the British war steamers are of such great importance in a national point of view, as the British navy is considered to be almost the sole national defense, that the fate of political parties and of naval administrations depends on the British public believing their vessels to be superior to any which can possibly be built by other nations. There is thus so much of personal, pecuniary, and political interest at stake in regard to the Admiralty's vessels, that the reports concerning their performance can be confidently accepted only in the cases where those interests are not involved, and in those cases there is always a considerable positive slip. For the most part, the speeds reported should be received with some reserve.

Did the space allow, a long list of trials of vessels might be selected from these official reports, in which the same vessel propelled by the same screw, gave, on different trials, widely different slips. Indeed, so great are the incongruities and inconsistencies, so evident and large are the errors, that the data can not be used for the determination of any engineering fact requiring absolute accuracy. It is much to be regretted, from a professional point of view, that the immense mass of engineering information comprised in the Admiralty reports should be so doubtful and so incomplete as to make it available for only approximate results.

VIII.

COALS OF ALABAMA.

By Hiram Haines, C. E., M. E.

The seismic convulsion that brought to the surface the archæan rocks which form the falls of the Potomac at Washington, the James at Richmond, the Appomattox at Petersburg, the Savannah at Augusta, and the Coosa River in Alabama, near its confluence with the Tallapoosa, produced waves, folds and dislocations in the overlying strata westward and parallel to this line of disturbance which brought to light the great deposits of coal occupying the region contiguous to the Apalachian chain. The coal measures which originally overspread the larger part of the northern half of Alabama, and the horizon of which formed the extreme southern limit of what is now known as the Apalachian coal field, was disrupted by these folds and divided into three separate coal-fields, distinguished by the names of the rivers that drain them, the Warrior, Cahaba and Coosa. The principal fold is that which formed the anticlinal valley between the Warrior and Cahaba coal-fields, exposing the Silurian limestone with its rich deposits of brown hematite ore, and breaking in two and forming as bold escarpments to the lateral ranges of hills, the vast stratum of fossiliferous iron ore that can be traced continuously along this upheaval from Alabama to New York, but which here assumes its greatest proportions. A cross cut of this seam of ore, almost within the corporate limits of the City of Birmingham, situated in this valley, measures about thirty feet in thickness, yielding in the furnace 50 per cent. of metallic iron. This enormous stratum of iron ore, associated with the extensive deposits of limonite ore with which the valley abounds, and flanked upon either side with inexhaustible beds of coal, presents a region possessing material resourses of commerce and war, contiguous

to the Gulf, which promises to be of great importance, not only in moulding the industrial character of a very large proportion of the people of this and the adjacent States, but in developing foreign commercial relations which must add largely to the naval and maritime consequence of our Gulf ports. The unquestionable facts before us also, that pig iron is now produced in this region at a cost of less than $8.00 per ton; that steam coal can be delivered at the mines on board the cars at a cost for labor of 50 cents per ton, together with a recent authoritative statement that open-hearth basic steel can be made here for less than $17.00 per ton, within ten hours by rail of Pensacola, imparts an especial interest and significance in the contemplation of the strategic position of the naval station situated at this point, with which it has not heretofore been regarded.

Hon. Abram S. Hewitt, in an address before the American Polytechnic Association some years ago, said of this region: "It is, in fact, the only place on the American Continent where it is possible to make iron in competition with the cheap iron of England. * * * This region, so exhaustless in supplies, so admirably furnished with coal, so conveniently communicating with the Gulf, will be of infinitely more consequence to us for its iron than it ever has been for its cotton. I think it will be a region of coke-made iron on a scale grander than has ever been witnessed on the habitable globe."

Upon the completion in 1873 of the South and North Alabama division of the Louisville and Nashville Railroad, (which has been the chief promoter of the development of the iron and coal of this region) the total production of iron in Alabama was 22,283 tons. The production during 1887 was 292,762 tons. The total output of coal for the year 1874 was 49,880 tons, and in 1887 it was 1,950,000 tons, (which was largely increased in 1888,) about 600,000 tons of which were converted into coke. This remarkable progress in development has transpired chiefly within the last ten years. Of the three coal-fields of the State, the Warrior is the most important in respect of superficial extent, aggregate thickness of its coal seams, and in production of coal. It possesses an area of over 7,000 square miles, and embraces about thirty

distinct seams of coal, ranging from 18 inches to 14 feet in thickness, and produced in 1887 about 1,500,000 tons. The present production from this field is, however, derived from but few of the seams, the Pratt seam alone (4 ft. 6 ins. thick) yielding one-half of the entire production of the State. The Cahaba field, next in importance, has an area of 435 square miles, and an annual production of about 320,000 tons. The coal measures of the Coosa coal-field cover an area of 415 square miles, but have been developed to a very limited extent, the production from this field for 1887 being 52,000 tons.

A summary of the outputs from the mines of the State for 1887 is as follows:

WARRIOR COAL-FIELD.

Names of companies.	Names of mines.	Production.	No. of openings.
Tenn. Coal and Iron Co.*	Pratt	711,606	4
Sloss Iron & Steel Co.	Coalburg (Pratt Seam)	189,555	4
Watts Coal & Iron Co	Warrior	23,000	3
Warrior Coal & Coke Co.	"	42,050	7
Mabel Mining Co.	"	30,000	1
Pierce Coal Co	"	51,900	3
Hoene Coal Co.	"	58,220	3
Milner Coal Co.	Newcastle	65,000	2
Woodward Iron Co.	Woodward (Pratt Seam)	60,676	1
J. S. Carr & Co	Morrow Mines	110,000	1
Corona Coal Co.	Corona Seam	20,000	1
Wolf Creek Coal Co.	Wolf Creek	530	1
Penn. Mobile Coal Co	Corona	44,000	1
Norrel & Co	Day's Gap	13,758	1
O'Brien Coal Co.	"	10,500	1
E. Donaldson & Co	Coal Valley	14,000	2
Va. & Ala. Coal Co	"	60,000	3
Black Diamond Co.	Patton	12,500	1
T. H. Dunn & Co.	York	18,750	1
Friel & Moore	Horse Creek	15,000	1
Kansas City Co.	Carbon Hill	2,000	1
Cordova Coal Co	Cordova	10,000	1
A. Durie and others	Tuscaloosa	8,250	2
Total		1,571,295	

* The output of the Tenn. Coal and Iron Co. at Pratt mines during the month of March of this year exceeded 100,000 tons, and the total production of coal in Alabama for 1888 will probably reach 3,000,000 tons, or about 50 per cent. more than that of 1887.

CAHABA COAL-FIELD.

Names of companies.	Names of mines.	Production.	No. of openings.
Brierfield Coal & Coke Co.	Brierfield	72,000	2
Cahaba Coal Co.	Blocton	157,821	6
Montevallo Co.	Aldrich	36,555	1
Stonestreet Co.	Stonestreet	15,000	1
Henry Ellen Co.	Henry Ellen	41,000	2
Total		322,376	

COOSA COAL-FIELD.

Names of companies.	Names of mines.	Production.	No. of openings.
Coosa Coal Co	Broken Arrow	None.	
St. Clair Coal Co	Ragland	52.141	1

The average wages paid miners per ton for "run of the mines" (steam coal) is 51 cents, and the average selling price per ton on board cars at the mines is $1.15.

The following analyses indicate the respective qualities of most of these coals:

	Specific gravity.	Sulphur.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Warrior Coal & Coke Co.	.....	0.56	.....	32.24	65.12	1.27	Warrior seam.
Watts Coal & Coke Co.	.....	1.11	1.61	33.00	61.78	2.48	" "
Milner Coal Co.	1.29	0.32	1.36	31.79	64.71	1.82	Black Creek seam.
Tenn. Coal & Iron Co.	1.30	0.92	1.50	31.45	61.59	5.41	Pratt seam.
" "	1.29	0.47	1.07	32.08	64.30	2.08	" "
Sloss Iron & Steel Co.	1.32	1.69	0.93	30.50	65.54	3.01	" "
Cahaba Coal Co.	1.27	1.01	.....	41.04	55.79	3.20	Blocton, 3 feet 6 inch seam.
" "	.....	0.48	2.24	34.12	60.75	2.41	Blocton, 6 ft. seam.

It will be observed that the coals from the Warrior Coal and Coke Co. and the Milner Coal Co. mines (Black Creek seam) are comparatively low in sulphur and ash and high in fixed carbon, qualities which, combined, give them a superiority over the others for steaming and purposes of construction and repair. Of the latter, an official report of tests made at the Pensacola Navy Yard by a Board consisting of Commander J. T. McGlensey, Chief Engineer L. J. Allen and others in 1876, says: "The only means of ascertaining the steaming qualities of the coal at our disposal were a comparative trial with some known coal performing the same work. For this purpose the George's Creek, Cumberland coal, heretofore used in the machine shop boiler of Steam Engineering Department was selected, and a trial of each made in that boiler for one week, with the following results:

Total number of pounds of Black Creek coal used in six days' steaming.....	6,543.
Average number of pounds used per hour.....	45.3
Total number of pounds of ashes and sweepings from flues.....	360.
Total number of pounds of George's Creek coal used in six days' steaming...	7,086.
Average number of pounds used per hour.....	49.2
Total number of pounds of ashes and sweepings from flues.....	650.

"The total accumulation of soot in tubes of boiler (while using the Black Creek coal) was very slight, not exceeding that from good anthracite coal for the same period, and with no apparent injury to the metal of the boiler. In order to test the availability of the Black Creek coal for smithing purposes, a sufficient amount was distributed amongst the blacksmiths working in the Navy Yard, and they have all reported its smithing qualities excellent. Several large welds were witnessed by the board. This coal appears to contain but little sulphur, and the board is of the opinion that its steaming qualities are excellent, particularly when considered in reference to the small amount of ashes remaining after its consumption."

While the foregoing report is incomplete with reference to the evaporative power of the coal, it is nevertheless of much value in establishing the superiority of this (and other Alabama coals by comparative qualitative analyses) over the Cumberland coals for Naval purposes, and is suggestive of a more comprehensive and

exhaustive official report upon the subject. Experiments by Prof. O. H. Landreth at the Vanderbilt University, Nashville, Tenn., in 1885, give the following results, comparative of the qualities of Alabama, Pittsburgh and Cumberland coals:

Name of coal.	Pounds of water evaporated at 212 degrees, with one pound of coal.	Per cent. of non-combustible matter.	Name of State.
Cumberland	8.21	11.5	Maryland.
Pratt	8.04	7.4	Alabama.
Pittsburgh	7.63	7.4	Pennsylvania.
Warrior	7.73	4.6	Alabama.
Blocton	7.63	5.7	Alabama.
Black Creek	7.63	4.0	Alabama.

This exhibit goes further to sustain the opinions expressed in the concluding paragraph of the above report of the Naval Board, and supplies partially the deficiency referred to in regard to evaporative values.

The railways centering at Birmingham furnish at present the only means of transportation, and this is the point of departure in making freight charges from the principal mines in all directions. An improvement of the navigation of the upper Warrior river, under appropriations for Rivers and Harbors, is now in progress, which promises, in the future, a water line of transportation for the coals from the Warrior Coal-field to the Gulf.

IX.

NOTE ON SCREW PROPELLER ACTION.

By Assistant Engineer T. W. Kinkaid, U. S. Navy.

Other things being equal, the smaller a screw the more efficient it will be. This is due to the enormous amount of frictional resistance which must be overcome in driving screw blades in their oblique course through the water. Of course, as a general thing, any reduction in diameter—pitch remaining constant—is accompanied by increased slip, the aggravation of the loss by slip being often more than compensated by reduced friction owing to diminished area. When the surface of the original screw is excessive, a reduction of diameter may result in giving actually less slip than before the change.

The writer in course of examining a certain screw performance has been led to the belief that varying the pitch in a certain way not now employed would justify the reduction in diameter of many of the screws now in use. Screws as now made have (1) constant pitch, (2) pitch increasing from hub to periphery, (3) pitch increasing from forward edge to after edge.

While on this subject, it may be remarked incidentally that, as a rule, the maximum pitch of a screw should be given greatest weight in calculations for slip, and not the mean pitch, as is often done. For example, Mr. Wright, in his paper on "Steam Trials of H. M. S. *Iris*", (Trans. Inst. Naval Architects, 1879), gave data of the famous screw performances of that vessel in which the slip often appears as negative. The writer has not examined all of the values there given, but is convinced that the mean pitch was employed in computing the slip. To illustrate, in case of the original screw, pitch of leading edge was 17′ 2″, of after edge 19′ 2″, revolutions 91.04, speed of ship 16.577 knots. The slip given in Mr. Wright's paper is 1.57 per cent. negative, but when figured for maximum pitch it comes out 3.6 per cent. positive. Mr. Spangler advocated this view of the matter in Vol. I, No. 1, of

the JOURNAL, instancing a screw of axially expanding pitch. The principle should hold also in the case of a screw whose pitch expands from the hub outward, as the tip has by far the greatest velocity, and therefore the greatest resistance, of any part of the blade.

The screw performances whose inspection led to the present paper were those of the U. S. S. *Alliance* in 1886. A new screw of reduced area and of Griffith shape was tried in competition with the old screw, which was a true helix with a curved generatrix. Some data and results of the trials are given in tables I and II. The new screw was measured to detect any warpage that might have taken place in cooling, but no serious amount was discovered.*

In investigating the action of a propeller blade, Mr. Froude and others have adopted the expedient of taking a narrow helical element of the blade, which is, for practical purposes, a long, narrow plane surface, and assuming the reaction of the water upon this element to be the same as if the element were moved forward with the speed of the ship, and also across the path of the ship at right angles. The resultant motion is one oblique to the ship's path. On this principle Fig. 1 is constructed, the hatched figure representing the helical element in horizontal section. If $OC =$ speed of ship, and $OA =$ lineal velocity of blade element about the propeller axis, it is evident that OB represents the actual direction and velocity of the blade element through the water. The reaction is the same as if the blade were stationery, and were struck by a stream of water in the direction of and with the velocity BO. If an elastic body impinge upon a smooth surface, the rebound takes place so that the angle of reflection = angle of incidence; but in the case of an inelastic fluid, like water, the latter continues close to the surface struck, traveling along it with the original velocity of the fluid, minus loss by friction. In the case of the blade element, the relative velocity of blade and water is BO, and this is the velocity of the water along the blade after the impingement. Only the direction of the water is changed. The

* The pitch at a radius of 72 inches was from 8½ to 9¼ inches less than at a radius of 21 inches.—ED.

old components of the direction of the water were *OA* and *AB*; now they are *OH* and *EH*. *EG* represents the slip as usually understood. *HA* represents what might be called the rotational slip, as it is the velocity of rotation possessed by the water as it leaves the after edge of the blade. Of course the useful thrust is determined solely by *EG*, the rotational slip representing a dead loss of power. It is said that Mr. Thorneycroft regains some of the energy of the rotating water by means of his guide blade turbine propeller.

The foregoing graphic method of examining the slip of a screw was applied by the writer to the blades of the new screw constructed for the *Alliance*, the angles being taken at seven different radial distances from the axis. Fig. 2 shows the application, three different speeds of ship being used. It will be seen that the rotational slip for a given speed of vessel is constant for all parts of the blade. Not so, however, with the longitudinal slip. This is seen to be greatest at the tip of the blade, diminishing rapidly toward the hub. The result of this variation of slip must be that the cylindrical column of water repelled by the screw has a greater velocity at its exterior than at its axis, giving rise to countless eddies. In such a case those parts of the blade near the roots are not doing full duty, and are almost being dragged through the water at the expense of the parts nearer the tip. No wonder that a certain experimenter found that a large quantity of rope accidentally wound around the hub of a screw made no difference in the speed!

The remedy which seems to be indicated—as the physicians would say—is to increase the pitch at the hub and allow it to diminish toward the tip, thus exactly reversing present practice. This would give a uniform velocity to the column of water acted upon by the screw, and the latter need not be so large as a screw whose inner parts are almost useless. In the case of such a screw, the pitch at periphery should have greatest weight in computing slip, and not the maximum pitch.

As to the failure of the new screw to improve the speed of the *Alliance*, it would require a very complete investigation, covering many points, to arrive at a probable conclusion. It may have

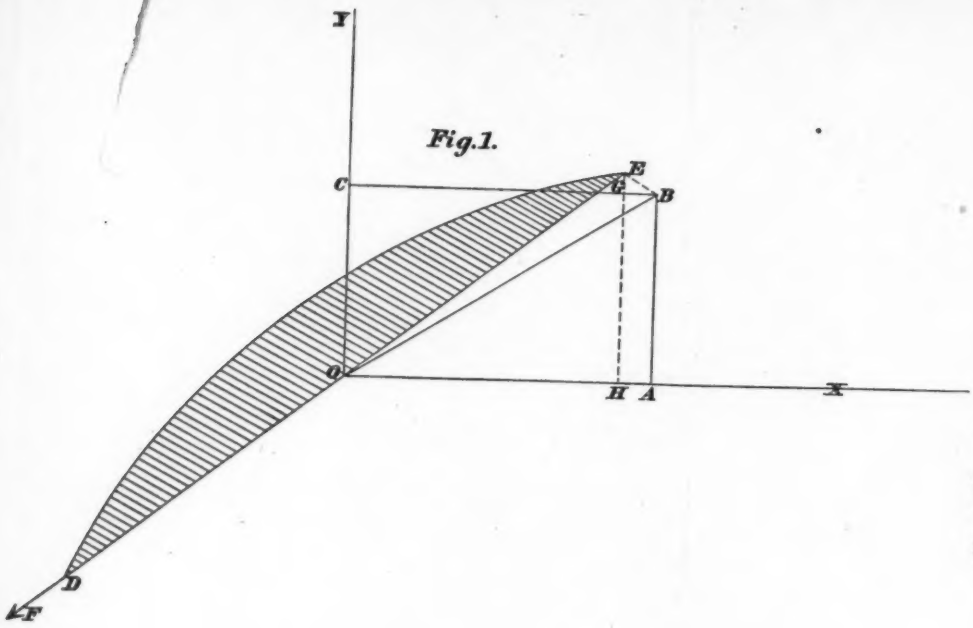
Y
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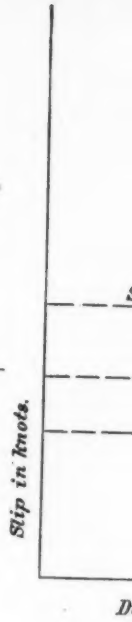
Fig.1.


Slip in knots.

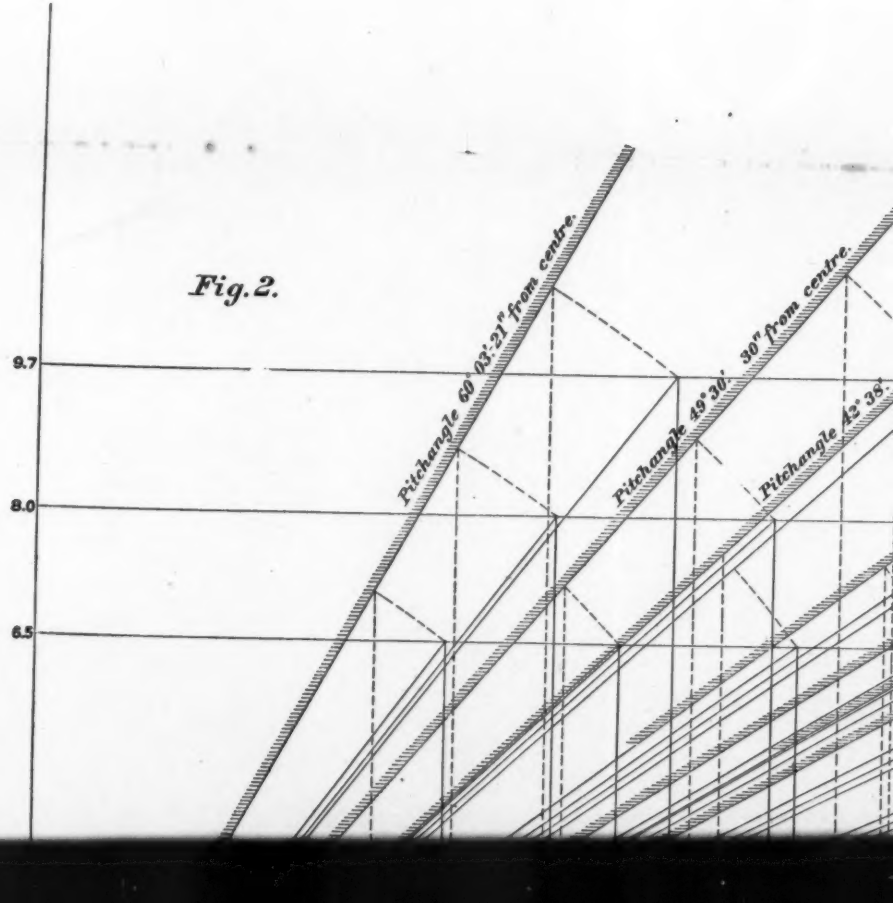
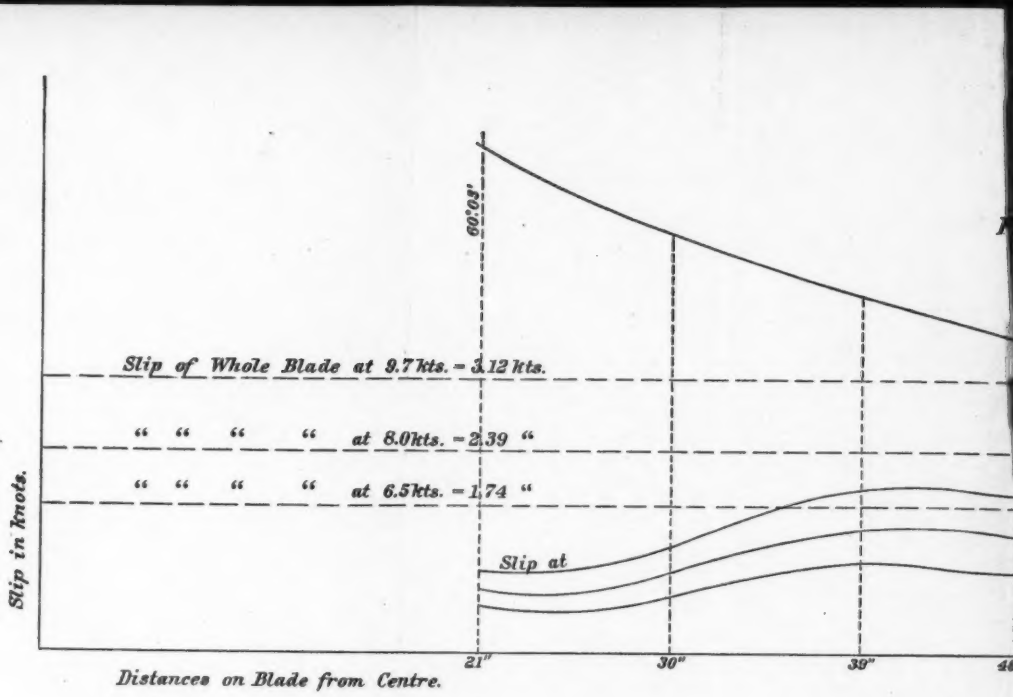
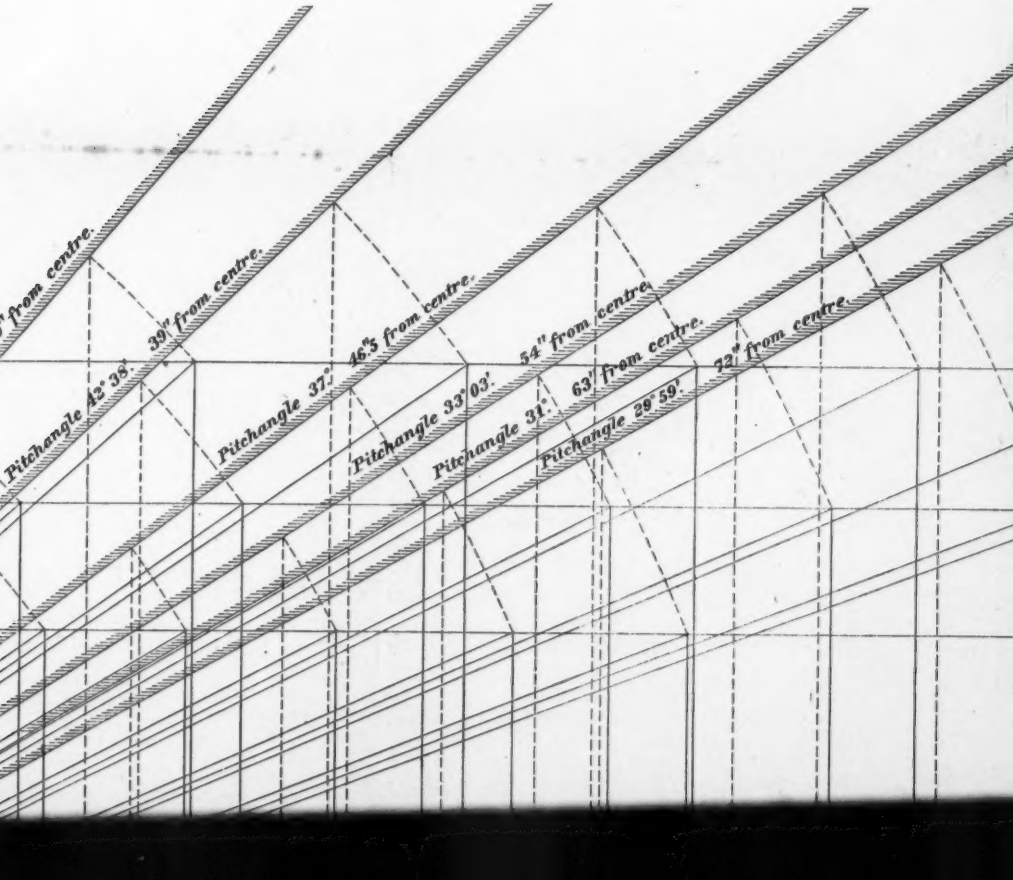
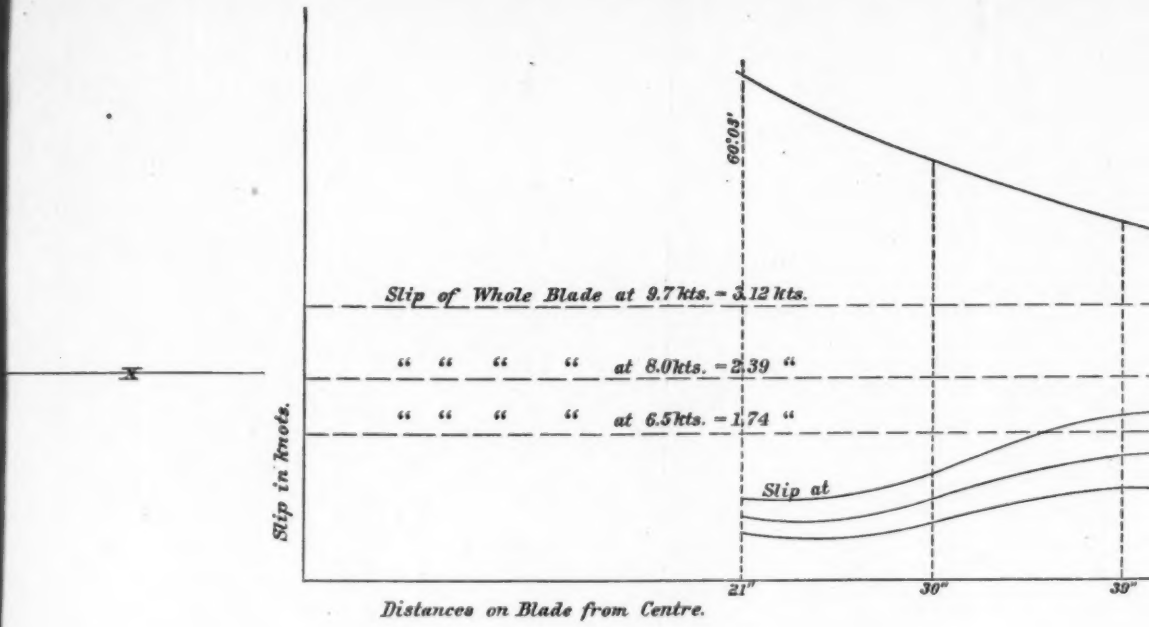

9.7
8.0
6.5
Pitchangle 60°03'.21" from centre.
Pitchangle 49°30'. 30" from centre.
Pitchangle 42°38'.

Fig.2.


60°03'
Slip of Whole Blade at 9.7 kts. = 3.12 kts.
" " " " at 8.0 kts. = 2.39 "
" " " " at 6.5 kts. = 1.74 "
Slip at
Slip in knots.
21"
30"
39"
Distances on Blade from Centre.


" from centre.
39" from centre.
Pitchangle 42° 38'.
Pitchangle 37° 46'5 from centre.
Pitchangle 33° 03'.
54" from centre.
Pitchangle 31°.
63" from centre.
Pitchangle 29° 59'.
72" from centre.


60°09'
Slip of Whole Blade at 9.7 kts. = 3.12 kts.
" " " " at 8.0 kts. = 2.39 "
" " " " at 6.5 kts. = 1.74 "
Slip in knots.
Slip at
21"
30"
39"
Distances on Blade from Centre.

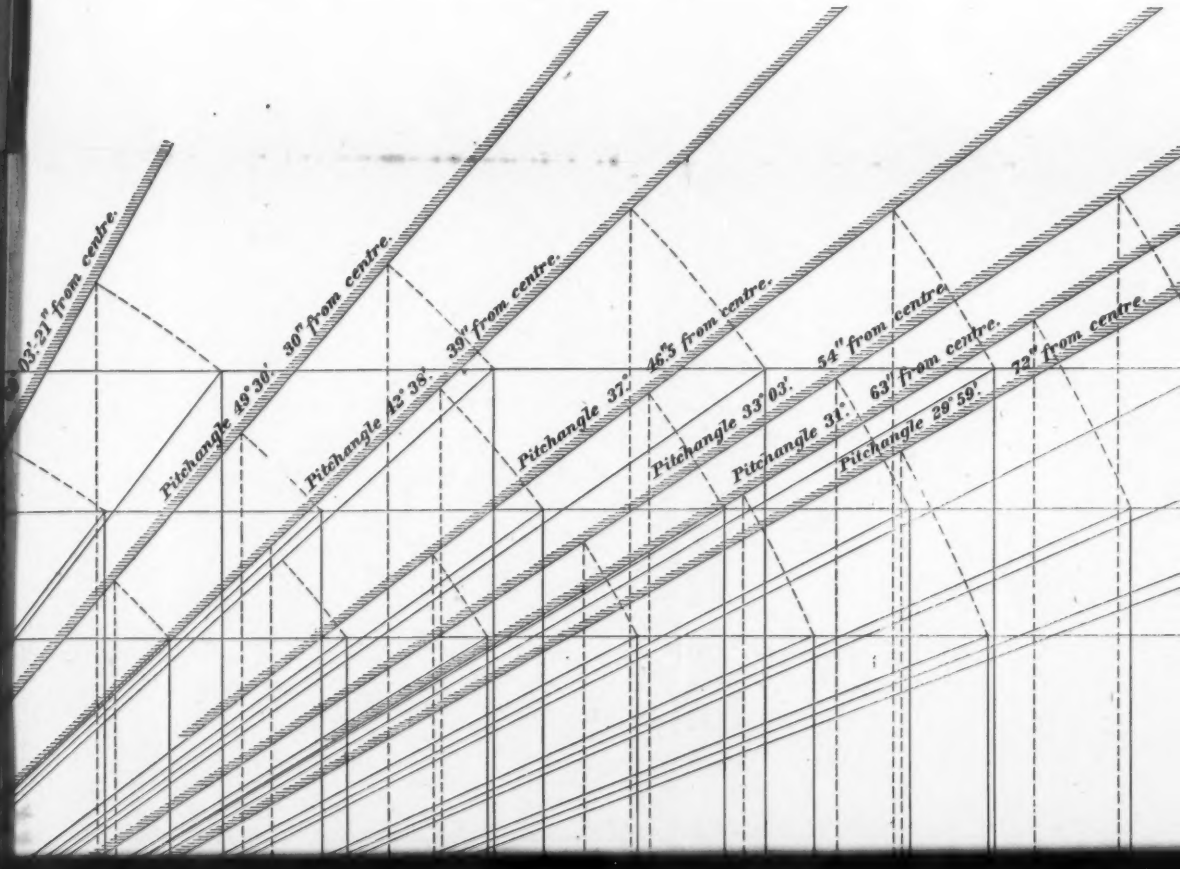
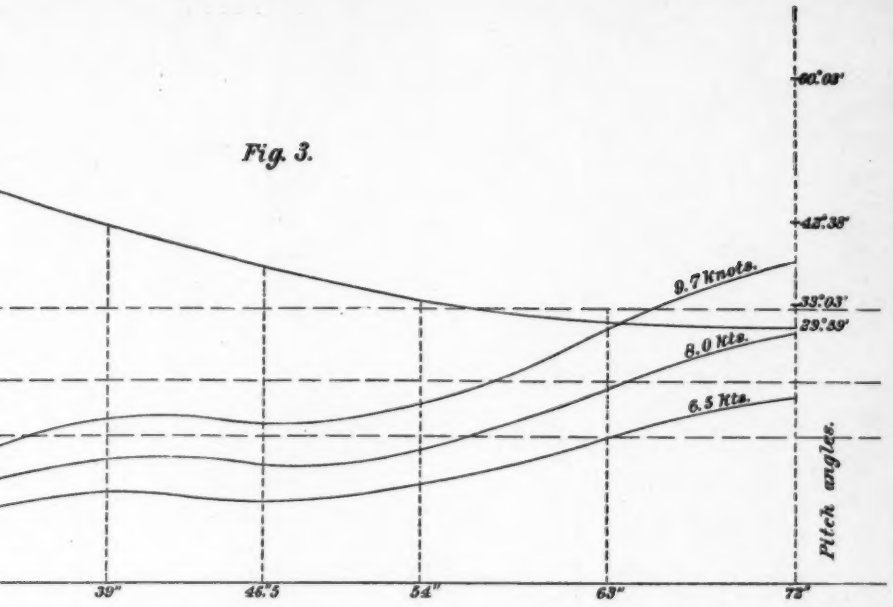
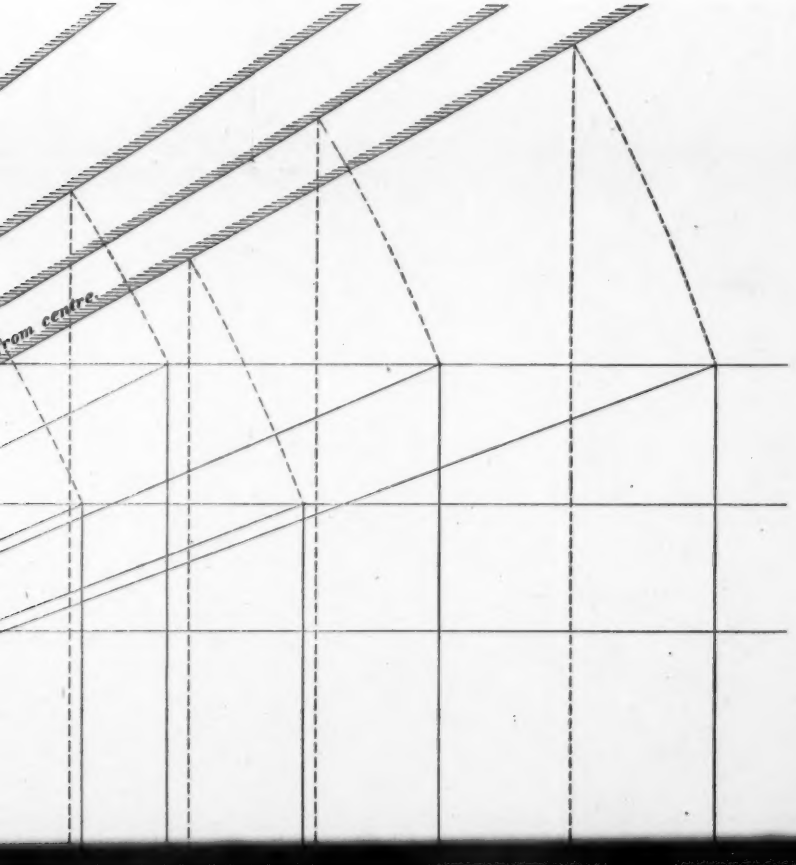

03'.21" from centre.
Pitchangle 49°30'. 30" from centre.
Pitchangle 42°38'. 39" from centre.
Pitchangle 37°. 46'.5 from centre.
Pitchangle 33°03'. 54" from centre.
Pitchangle 31°. 63" from centre.
Pitchangle 29°59'. 72" from centre.

Fig. 3.


60°.03'
42°.38'
33°.03'
29°.39'
9.7 knots.
8.0 kts.
6.5 kts.
Pitch angles.
39"
46".5
54"
63"
73"


rom centre.

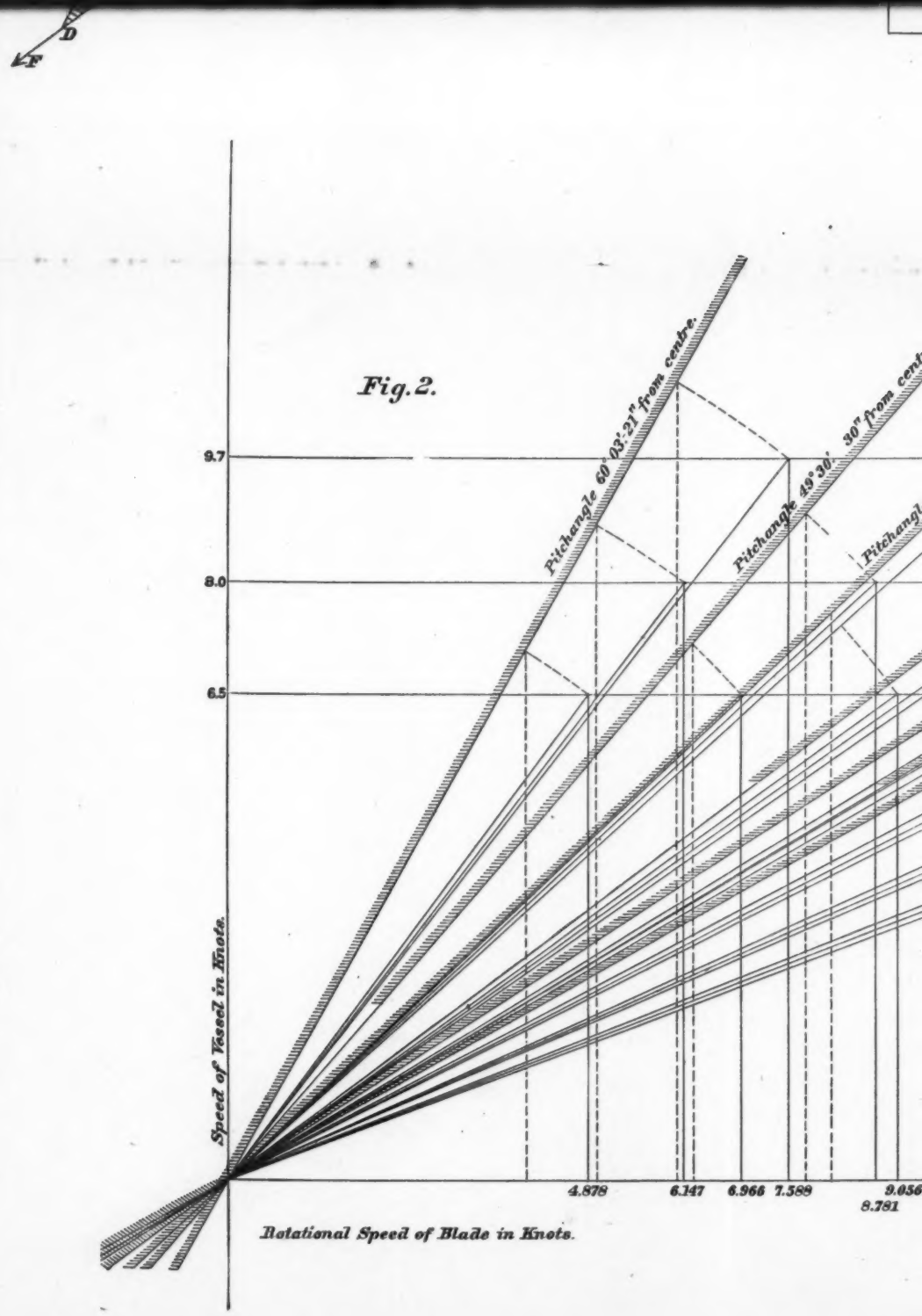

D
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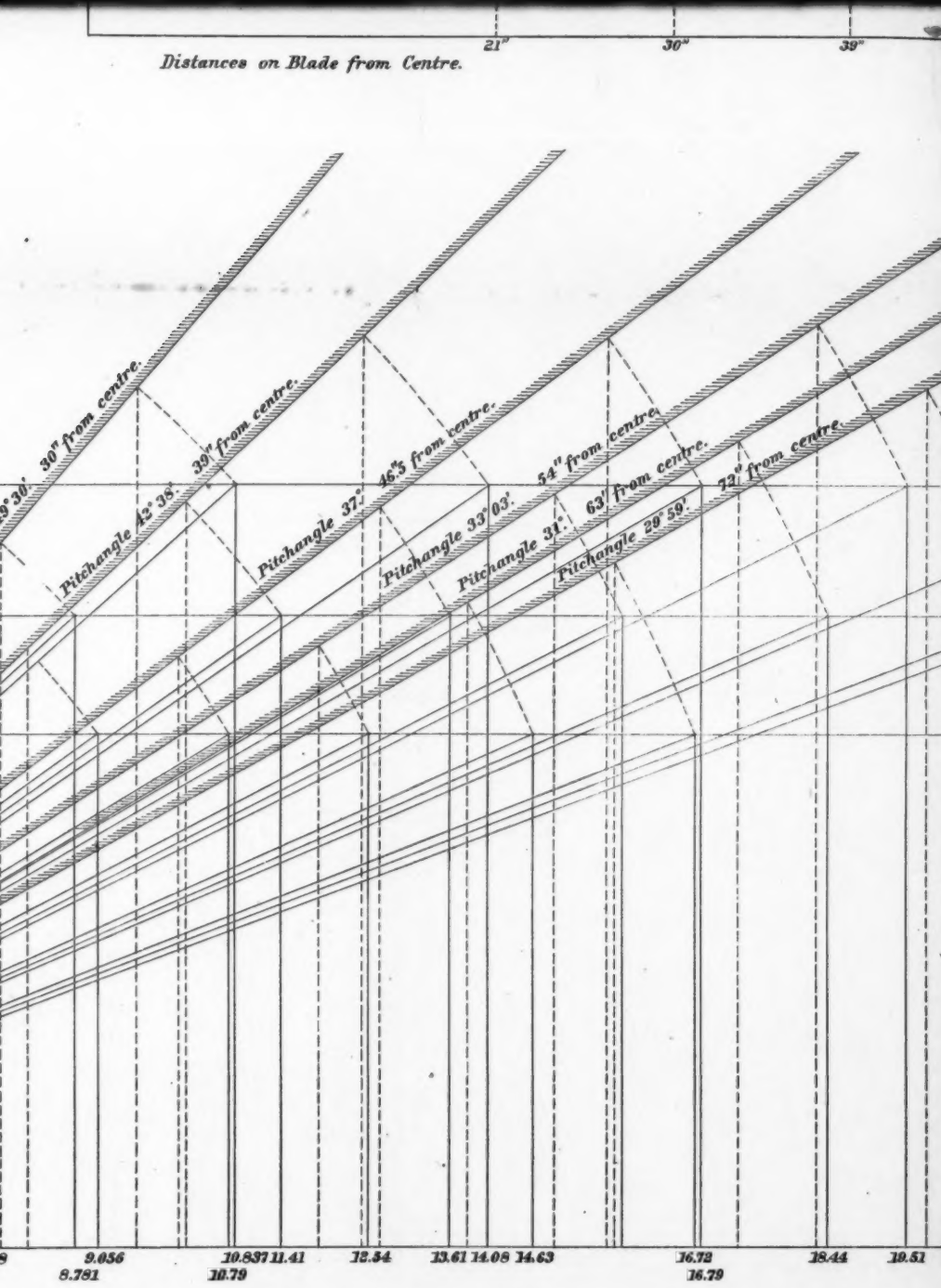
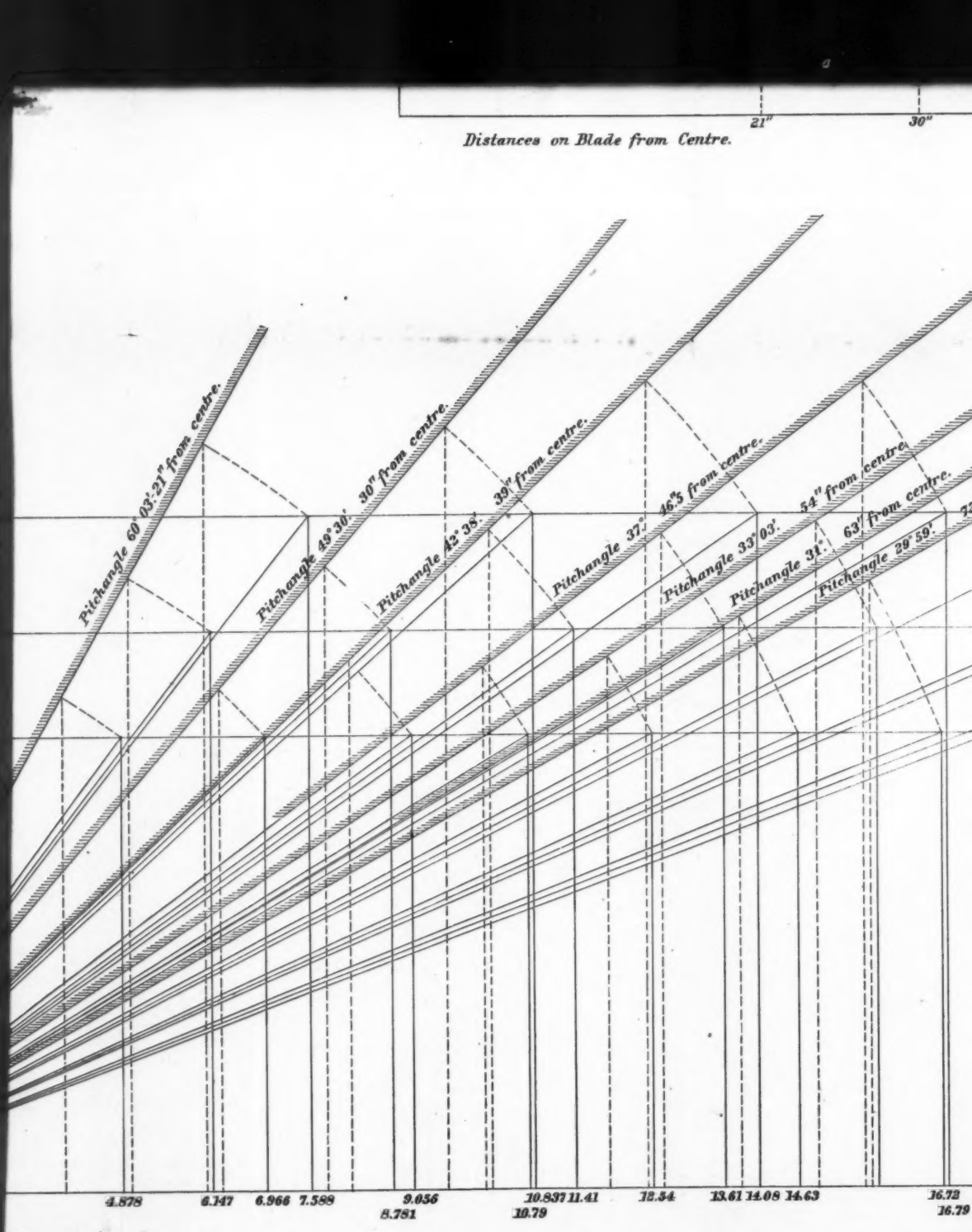
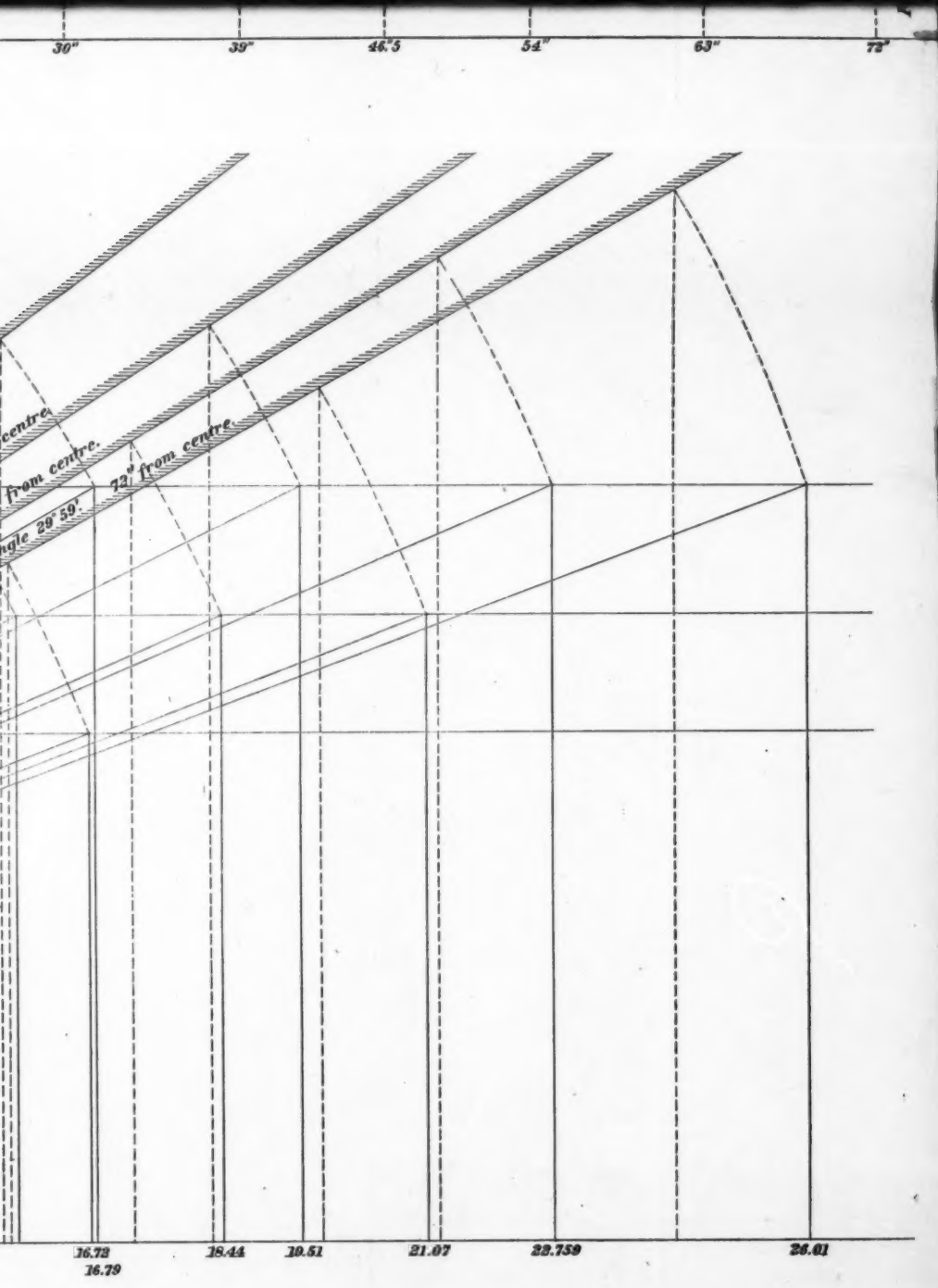
Fig. 2.
9.7
8.0
6.5
Pitchangle 60° 03' 21" from centre.
Pitchangle 49° 30' 30" from cent
Pitchangl
Speed of Vessel in Knots.
4.878
6.147
6.966
7.589
9.036
8.781
Rotational Speed of Blade in Knots.


21"
30"
39"
Distances on Blade from Centre.
9° 30'. 30" from centre.
Pitchangle 42° 38'. 39" from centre.
Pitchangle 37°. 46.3 from centre.
Pitchangle 33° 03'. 54" from centre.
Pitchangle 31°. 63" from centre.
Pitchangle 29° 59'. 72" from centre.
9.056
8.781
10.837 11.41
10.79
12.34
13.61 14.08 14.63
16.72
16.79
18.44
19.51


21"
30"
Distances on Blade from Centre.
Pitchangle 60° 03' 21" from centre.
Pitchangle 49° 30' 30" from centre.
Pitchangle 42° 35' 39" from centre.
Pitchangle 37° 46'5 from centre.
Pitchangle 33° 03' 54" from centre.
Pitchangle 31° 63" from centre.
Pitchangle 29° 59'
4.878
6.147
6.966
7.588
8.781
9.056
10.79
10.837
11.41
12.54
13.61
14.08
14.63
16.72
16.79
ade in Knots.


30"
39"
46.5
54"
63"
72"
centre.
from centre.
ngle 29° 59'.
72° from centre.
16.72
16.79
18.44
19.51
21.07
23.739
26.01

been due to increased "augmented resistance" of hull, increased hub resistance, and so forth; and it is quite certain that the run of the *Alliance* is not adapted to the modern high speed screw. No diagram like Fig. 2 was made for the old screw; but as this screw was not of radially expanding pitch, the results would be similar to those in Fig. 2.

TABLE I.—DIMENSIONS, &c.

	Original Screw.	Modified Griffith.	
	Measured.	Designed.	Measured.
Diameter of screw..	14 feet.	12 ft. 6 in.	.....
" " hub....	20 inches.	37½ inches.	.....
Pitch.....	18 ft. 9 in.	18 feet.	18 ft. 7 in.
Projected area.....	54.64 sq. ft.	37.63 sq. ft.	.....
Helicoidal "	70.5 " "	50.0 " "	.....
Weight.....	7,900 lbs.	10,881 lbs.	10,398 lbs.

TABLE II.—PROGRESSIVE SPEED TRIALS.

Knots.	Old Screw.		Modified Griffith.		Difference.
	I. H. P.	Rev's.	I. H. P.	Rev's.	I. H. P.
6.5	200	38	267	45	67
7.0	245	41	315	49	70
8.0	343	47	458	56.7	115
9.0	465	53	690	64.3	225
9.7	585	57	1000	70	415
10.8	850	65	.....	...	.....

[This note was prepared by Mr. Kinkaid without the knowledge that anything had been done in the same direction. It appears, however, that an English patent was issued to Mr. A. T. Zeise, of Ottensen, Germany, in 1886, and one in this country last year, for a propeller constructed according to this principle.

Several propellers have been constructed in Germany under Zeise's patent, and are said, by the inventor's American agent, to give excellent results. One is being made by the Fulton Iron Works, of San Francisco, for a vessel on the Pacific Coast, and we hope to publish a report of the trial.

Briefly stated, Zeise's propeller is designed by determining, as usual, the necessary pitch for securing the desired speed. This is the pitch at the periphery. The product of pitch and diameter is then made constant at all points of the blade, so that the pitch at any point inside the periphery is equal to this constant quantity divided by the diameter at that point.

No information is given in the patent specifications in regard to any reduction of area of blades consequent on the increase of efficiency claimed.—ED.]

X.

NOTES ON INSPECTION AND MANUFACTURE OF STEEL PLATES.

By Assistant Engineer A. M. Hunt, U. S. Navy.

Steel for our new vessels is subjected to surface inspection, tensile, bending, quenching and chemical tests.

Surface Inspection.—The duties of the surface inspector are to examine the plates rolled, for surface defects, such as pits, cracks, snakes, blisters, lamination at edges, clay marks, and evidences of overheating or cold rolling. He also marks out the test pieces, bearing in mind that his tests should be taken from the worst part of the plates, and that special tests should be taken from plates which he has reason to suspect have been overheated or cold rolled, if the specifications are so drawn as to allow this to be done.

The first requisite for surface inspection is a suitable hammer. It should have cylindrical ends, with faces at right angles to the axis, edges slightly rounded, and should weigh from four to six ounces. One face should be $\frac{3}{16}$ inch in diameter and the other $\frac{3}{4}$ inch.

The first point to note is whether or not the ingot, as drawn from the reheating furnace, appears too hot. The inspector should then watch the rolling and inspect the material as it comes from the rolls. If the plate finishes with uneven and ragged edges, this fact is good evidence that the ingot was overheated. A tensile test piece should be taken from such ragged edge, and the heat at which the finishing passes through the rolls are made noted. The plate should be finished at or above a decided red heat, and any plate which is finished too cold should have a special tensile test piece taken from it. A cold bending test might show the effect of the cold rolling—a tensile test will certainly do it.

The inspector should not stand directly over, nor on the plate to be inspected, but his line of vision should strike the plate at an acute angle. Many defects which are invisible when the eye is directly over them become plainly apparent when looked at from the side.

Pits are generally filled with scale, and are evident on account of the difference in color from the body of the plate. A few sharp blows with the hammer will dislodge the scale, and the depth of the pit can be seen. If shallow they may not affect the plate, but care should be exercised that a plate is not passed which, by reason of numerous small pits and scale marks, has a roughened surface. The worst examples of pitting that have ever come to my notice were in protective deck plates. The whole surface in some plates was dotted with pits, oval in shape, from $\frac{1}{2}$ to $1\frac{1}{2}$ inches in length, and from $\frac{1}{4}$ to $\frac{3}{4}$ inch wide, and from $\frac{1}{16}$ to $\frac{3}{16}$ inch deep. They were filled flush with scale which could easily be dislodged with a hammer.

Cracks and snakes are usually detected without much trouble. They are sometimes covered with a thin layer of scale, and unless this is removed, may escape notice. A crack should at once reject a plate.

Occasionally a plate will be found which has a patch of sand or clay rolled into it, and spread out on the surface. This generally comes from the bricks on which the ingot rests in the reheating furnace. The judgment of the inspector will determine whether the extent of the defect is sufficient to reject the plate.

Blisters are of very infrequent occurrence. The only cases which I have seen were caused by foreign substances, such as clay, becoming entangled in the metal when cast.

Plates are sometimes laminated at the edges and ends, due apparently to the metal drawing more rapidly at the top and bottom surfaces than in the middle. Enough allowance is generally made in the size of the plate, so that these laminations are rejected in shearing, but heavy plates, in which this lamination is noticed, should have the edges examined after shearing to ascertain if it has all been removed.

At the Homestead Mill, only the upper surface of the plates,

as rolled, is inspected. The mill is a three-high one, and the shaking which the plate receives as the tables are raised and lowered seems to be sufficient to dislodge all scale and foreign matter from the bottom. Very few plates have been returned on account of defects on the under side. When rolled on a two-high reversing mill, experience domonstrates that defects are as apt to be found on the bottom as on the top of the plate, and the plate must be examined on both sides.

When rolling thin plates of 12½ pounds per square foot or under, if the ends are ragged, scraps of the metal sometimes break off, and, being carried around by the roll, are forced into the body of the plate. The surface inspection cannot be too rigidly carried out, as the benefit of the tensile tests may be entirely annulled by carelessness in this part of the work.

Experience alone can enable one to detect, at a glance, hidden defects, and no better advice can be given to the beginner than to use his hammer on all suspected places.

Tensile Tests.—For ship plates, four test pieces are selected to represent the heat. For boiler material, each plate is tested. For forgings, the manner of taking tests varies. For boiler and ship plates, the test pieces are of uniform rectangular section throughout, as near as they can be finished. Measurements of width and thickness are taken with a micrometer gauge measuring to thousandths of an inch. If the piece is taper, and the taper exceeds six or eight thousandths of an inch, it should be returned to the machine shop for correction, as it will probably break near the grips, if not in them, so giving a reduced elongation.

After the pieces are measured, the beam of the machine should be in balance with the weights at zero mark. A change in the counterpoise may alter the results several thousand pounds.

The manner of securing test pieces in the machine, and methods of applying loads, vary with the machine, and are given in standard books on testing. In order to be perfectly certain of his results, the inspector should apply the loads himself, as, by improperly manipulating the jockey weight, results that are either too low or too high can be obtained.

The cold bending and quenching tests are selected in the same

manner as tensile tests. A heat or plate which passes the required tensile tests rarely fails on the bending tests. The pieces are bent either with a hydraulic press or under a steam hammer. They are generally bent through an angle of from 100° to 120° in a die before being crushed down flat. The pieces to be quenched are heated to a bright cherry red, preferably without contact with the fire, and then quenched in water at a temperature of 82° Fahr. They are then bent in the same manner as cold bending pieces. To illustrate the splendid qualities of mild steel, a piece three inches thick, cut from a plate made at the Homestead Steel Works, was bent double, and flattened on itself cold without showing any signs of distress.

All tensile and bending test pieces should have the edges planed to remove the metal affected by the shearing. The greater the thickness of the plate the greater the amount which should be removed.

Up to the present time the only chemical requirement for steel supplied for the Navy has been a limitation of the phosphorus. This element seems to render the steel unreliable when present in any quantity, and it segregates largely, so giving spots in the ingots which are much richer in phosphorus than others. The limitation was first applied to boiler plates, but in the later specifications the phosphorus is limited in all material.

Area of Test Pieces.—The present specifications require all test pieces to have an area of from five to eight-tenths of a square inch, regardless of the thickness of the plate. Under this rule, the width of the test pieces cut from the heavy boiler plates now made is less than the thickness. It seems right that the rule should be modified for these heavy plates. The amount of skin or rolled surface which the test piece has influences the tensile strength which it will show. In actual use, the plate has the advantage of this skin resistance, and the width of the test piece should be at least equal to the thickness of the plate. The error is on the right side, but the results do not show the characteristics of the metal as it exists in the plate.

Variety in Shape and Dimensions of Test Pieces, and Influence on Results.—All tensile tests of structural and boiler steel for the

Navy must have a uniform rectangular section for eight inches, in which length the elongation is measured. The test piece required by the supervising inspectors of steam vessels, under the U. S. Inspection laws, brings the stress on a narrow neck formed by slotting out a circular arc with a chord of about an inch on each side, leaving the width about an inch. No elongation is measured, and the reduction of area is taken as a measure of the ductility of the metal. This form of test piece,* is used nowhere else, and is disapproved by most recognized writers on the subject. In order to show what discordant values for the tensile strength are given when different shapes are used for the test piece, the following tables have been compiled from the records of tests made at various mills in and around Pittsburgh:

TESTS OF BOILER PLATES.—$1\frac{1}{16}$ *inch thick.*

No.	Tested in a length of eight inches.					Tested in marine section.	
	Mark.	E. L. per sq. in.	Tensile per sq. in.	Elong. per cent.	R. of A. per cent.	Tensile per sq. in.	R. of A. per cent.
1	3518–2	37,940	60,120	20.0	42.05	72,500	36.7
2	3518–3	36,620	57,400	24.5	46.55	72,410	46.0
3	3518–4	35,450	58,280	23.75	48.65	72,720	49.9
4	3518–5	34,000	58,530	28.0	45.9	70,960	49.6
5	3520–1	35,430	57,940	23.5	48.15	73,200	45.0
6	3520–2	38,680	62,820	23.0	43.75	76,070	39.7
7	3522–2	35,090	56,800	27.5	52.0	69,160	51.3
8	3526–1	33,760	58,460	31.25	53.4	68,280	46.5
9	3526–2	33,100	57,090	26.25	59.9	71,000	52.1
10	3526–3	34,400	56,340	25.0	48.95	70,030	44.4

ANALYSES.

	C.	*Mn.*	*Si.*	*S.*	*P.*
1, 2, 3, and 4	.16	.49	.....	.....	.....
5 and 6	.17	.52	.013	.031	.034
7	.18	.47	.....	.....	.....
8, 9, and 10	.19	.48	.....	.....	.....

* Known also as the "marine section."

It will be seen that the tensile strength as given by the marine section is from ten to fifteen thousand pounds higher than when tested in a length of eight inches.

This difference becomes less as the thickness of the test piece diminishes, and in pieces $\frac{1}{4}$ inch thick is about three to four thousand pounds.

TESTS FROM SAME PLATE.—0.306 *inch thick.*

	Tensile per sq. in.	Elongation.	
		per cent.	Measured in
Longitudinal	66,840	36.0	2 inches.
Transverse	72,480	29.0	
Longitudinal	67,280	29.5	4 inches.
Transverse	71,095	24.0	
Longitudinal	63.720	26.75	8 inches.
Transverse	68,400	16.5	

ANALYSIS.—$C = .16$, $Mn = .38$, $Si = .012$, $S = .045$, $P = .097$.

The second table shows how the percentage of elongation varies with the length in which it is measured. It will also be noticed that the tensile strength is greater in the short piece. Another point to be observed is that the transverse test pieces give a higher result in tensile strength, and a lower result in elongation.

Writers frequently speak of metal giving a certain tensile strength and a certain percentage of elongation. Not a word is said concerning the shape or size of test piece, nor of the length in which elongation is measured. Such remarks do not give half so satisfactory an idea of the quality of the metal as the results of measured mile trials of ships give of the results which will be obtained in actual cruising. The answer which a steel manufacturer is apt to give to a question as to whether he can make steel of a given tensile strength and percentage of elon-

gation is, What is to be thickness of the material, the size and style of test piece, and in what length is the elongation to be measured?

Influence of Temperature of Finishing Passes on the Tensile Strength of Steel.—It is often considered by engineers and others that if the chemical composition of a particular steel is known, the tensile strength can be approximately calculated. Thurston and others give formulæ for calculating the tensile strength of steel, knowing the percentage of carbon. As a matter of fact the tensile strength of rolled material depends largely upon the treatment the steel receives at the rolls. The difference in tensile strength between two plates from ingots of the same heat, one finished as hot as possible, and the other at as low a heat as will give a visible red, may be several thousand pounds. The elastic limit is probably affected even more than the tensile strength by difference in treatment.

Opposite the ingot number and size of plate in the roller's book, may often be noticed directions like these: "Finish very hot;" "Finish cold;" "Finish as cold as possible." Steels of quite varying composition may be made to show the same physical characteristics, at least as regards tensile strength, by varying the treatment at the rolls.

Advantages of a Built-up Crank Shaft of Steel over one Forged Solid from an Ingot.—For making a solid forged, two-throw crank shaft of steel, an ingot is taken of an elliptical section slightly larger than the crank webs, and the shaft, instead of being forged from this ingot, is partially cut out under the hammer and rough hammered into shape. Some portions of the metal, as the crank webs, receive almost no work, and are kept hot for a long time without work. Heat without work is injurious to steel. The crank pins receive little or no work, and must, of course, have the same hardness as the other parts of the shaft, when they should be harder to wear well. This point receives attention in all specifications issued by the Steel Inspection Board for separately made wrist pins.

In a built-up shaft, each of the parts can receive ample work to improve the quality of the metal and to render it trustworthy.

Table showing the limiting sizes of rectangular plates of varying thicknesses, and largest diameter of circular heads rolled at Homestead Works.

Thickness.	Width of plate in inches.															Diameter.
	114	108	105	100	96	90	84	80	76	72	64	56	48	36	24	
7/16	.....	.....	120	150	180	200	225	245	260	275	310	365	430	500	500	110
1/2	.....	130	160	200	210	225	250	275	300	320	400	460	500	550	600	110
9/16	140	170	200	260	310	330	360	380	400	420	460	500	570	600	600	114
5/8	160	200	230	245	310	340	380	400	420	430	480	530	570	600	600	114
11/16	170	200	220	240	290	330	360	370	390	410	480	520	570	600	600	114
3/4	170	190	210	230	270	290	340	360	370	390	450	500	570	600	600	114
13/16	160	180	200	220	240	260	300	310	33c	350	400	480	530	600	600	114
7/8	160	180	190	200	220	240	260	280	310	330	380	430	500	600	600	114
15/16	160	180	190	200	210	220	250	280	300	320	360	410	480	540	600	114
1	150	170	180	190	200	215	245	260	280	300	340	380	450	540	600	114
1 1/16	140	160	170	180	190	205	220	230	260	270	320	360	430	540	600	114
1 1/8	130	150	160	170	180	195	215	230	240	250	290	330	380	500	540	114
1 3/16	120	140	145	150	160	175	190	210	220	230	260	300	350	440	500	114
1 1/4	110	120	125	140	145	155	175	185	195	205	230	265	310	400	500	110
1 1/2	110	120	120	135	140	150	170	180	190	200	225	260	300	400	500	110

Since the large universal mill at Homestead was finished, about last July, a number of blooms for shafts have been made on it. A large square or octagonal ingot is taken and rolled into a square slightly larger in section than the shaft to be made. In this way the metal is well worked, at an even heat, before it reaches the hammer, or may be at once placed in the lathe for rough turning. The subject of rolling an octagon section has been discussed, but not attempted. The largest ingot rolled in this way was a 40 x 40 inch ingot, weighing 35,300 pounds, which was rolled to a bloom 24 x 24 inches.

The metal in such a bloom is better worked, and in a more homogeneous condition as regards internal strains than if forged under a steam hammer, unless the hammer is an extremely powerful one. Solid forged steel crank shafts of large size, as I have seen them made, are, in my opinion, not equal to solid cast ones. In the solid forged ones the crank webs receive almost no work, and the metal in the webs is in the same condition as when cast, except that it has been weakened by repeated heating without work.

No physical tests have as yet been made on the metal from blooms turned out by the universal mill at Homestead.

XI.

CONTRACTORS' FULL POWER FORCED DRAFT TRIAL OF THE U. S. S. "YORKTOWN."

By Assistant Engineers Walter M. McFarland and Harold P. Norton, U. S. Navy.

The four-hour full power forced draft trial of the *Yorktown's* machinery was made by the contractors at sea, off Cape Henlopen, on February 13, 1889.

The *Yorktown* is a twin-screw steel gunboat, of 1,703 tons displacement, and was built by the Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, Pennsylvania.

Rig, three-masted schooner. Armament, six VI-inch B. L. R. and eight rapid-fire machine guns, besides being fitted with tubes for discharging torpedoes.

The following are some of the principal dimensions and data:

Length between perpendiculars	228 feet.
Beam, extreme,	36 feet.
Area of immersed midship section	435.3 square feet.
Depth in hold from top of main deck beams to top of floors	18 feet 9 inches.
Draught of water forward, 13 feet, / Draught of water aft, 15 feet, } mean	14 feet.
Rates of length to breadth	6.33 to 1.
Displacement per inch at L. W. L.	13.72 tons.
Area of L. W. L.	5,765 square feet.
Coefficient of fineness on midship section	.6005
Coefficient of fineness of L. W. L.	.7024
Sail area	6,352 square feet.
Transverse metacenter above center of gravity	2.58 feet.
Longitudinal metacenter above center of gravity	260 feet.
Moment to alter trim one inch	160 foot-tons.
The contract I. H. P. to be developed during the four-hour trial, including fire-room blowers, steering engine, and all pumps in use, was	3,000
Normal capacity of coal-bunkers	200 tons.
Maximum capacity of coal-bunkers	400 tons.
Displacement on trial	1,703 tons.
Coefficient of fineness on extreme dimensions	.4973

Engines.—There are two horizontal direct acting triple-expansion engines, working at 160 pounds boiler pressure.

The engines are placed one forward of the other, each one being in a separate water-tight compartment. The forward engine drives the port, and the after one the starboard propeller. The air, circulating and bilge pumps in each engine room are worked by a compound engine, the air and circulating pumps being single acting, and the bilge pumps plunger pumps. The axes of the pumps are vertical, and those of the engine cylinders almost horizontal. The engine and air and circulating pump connecting rods are connected to the same crank pins, and the bilge pumps are worked by horizontal arms projecting from the air pump crossheads.

There is one composition cylindrical condenser in each engine room, with the condensing water passing through the tubes. All the valves on the main engines are single ported piston valves; there being one for each high and each intermediate pressure cylinder, and two for each low pressure cylinder, and are worked by Marshall's valve gear, the high and intermediate pressure valves being operated direct, and the low pressure by a rock shaft. The cut off is varied by changing the position of the link blocks in rocker arms. The crank shafts and pins are of forged steel, made in one forging for the three cylinders with axial holes through the shaft and crank pins. The crossheads are fitted with slipper guides; and the main bearings and cylinders are tied together by the crosshead guides and a horizontal and diagonal tie rod for each bearing.

The crank pins are oiled by a centrifugal device, which delivers the oil into the center of the crank pin and from there it passes through holes to the surface of the pins.

The reversing gear consists of a single horizontal steam cylinder with a floating lever for controlling its valve, and there is no means provided for reversing by hand. The throttle is a double poppet-valve. All the principal bearings are faced with Parsons' anti-friction metal, and all shafting has an axial hole.

There is a Williamson steering engine in the after part of the after engine room, its valve being worked from the steering

wheels on deck. The main and auxiliary feed pumps are of the vertical duplex type, there being one main and one auxiliary pump in each fire room. In each engine room there is a horizontal bilge and fire pump, and in the forward engine room one centrifugal bilge pump.

The following are some of the principal dimensions and ratios of the machinery:

Number of cylinders.. (one engine)	3.
Diameter of H. P. cylinder	22 inches.
Diameter of I. P. cylinder	31 inches.
Diameter of L. P. cylinder	50 inches.
Stroke, common	30 inches.
Cranks at 120 degrees with each other, and in the following order for *ahead* motion, H. P., I. P. and L. P.	
Diameter of piston rods	3¼ inches.
Pistons are solid, in dished form, and made of cast steel. All pistons are fitted with an adjustable shoe, faced with white metal. Material of piston rods, forged steel.	
The cylinders are not steam jacketed.	
Diameter of H. P. valves	9 inches.
Area of steam port	54.4 square inches.
Area of exhaust port	149.2 square inches.
Diameter I. P. valves	15 inches.
Area of steam port	94.15 square inches.
Area of exhaust port	377.4 square inches.
Diameter of L. P. valves	17 inches.
Area of steam ports (both valves,)	211.1 square inches.
Area of exhaust ports (both valves,)	862.52 square inches.
Area main steam pipe	50.26 square inches.
Volume swept by H. P. piston per stroke	6.50 cubic feet.
Volume swept by I. P. piston per stroke	13.01 cubic feet.
Volume swept by L. P. piston per stroke	33.99 cubic feet.
Diameter of reversing cylinder	8 inches.
Stroke of reversing cylinder	15 inches.
Clearance H. P. cylinder per cent	22.5
Clearance H. P. cylinder in inches of stroke	6.77
Clearance I. P. cylinder per cent	19.2
Clearance I. P. cylinder in inches of stroke	5.76
Clearance L. P. cylinder per cent	12.36
Clearance L. P. cylinder in inches of stroke	3.707
Ratio of net area of H. P. piston to I. P. piston	1 to 2.
Ratio of net area of I. P. piston to L. P. piston	1 to 2.613.
Ratio of net area of H. P. piston to L. P. piston	1 to 5.226.

Length of connecting rod between centers	64 inches.
Diameters of connecting rod	3¾ and 4 inches.
Diameter of crank shaft	9 inches.
Diameter of crank pin	9 inches.
Diameter of hole in crank shaft	3 inches.
Diameter of hole in crank pin	3 inches.
Crank webs, length	11 inches.
Crank webs, thickness	6½ inches.
Diameter of line shaft	9 inches.
Diameter of hole in line shaft	3 inches.
Diameter of thrust shaft	9 inches.
Diameter of hole in thrust shaft	4 inches.
Diameter of propeller shafts	9¾ and 11½ inches.
Diameter of hole in propeller shaft	4 and 7 inches.
Length of port shafting	78 feet 7 inches.
Length of starboard shafting	57 feet 5 inches.

The outboard sections of propeller shafting are cased with composition $\frac{7}{16}$ inch thick. The flange couplings are 18 inches diameter and 2½ inches thick. The thrust bearing is of the collar type, the rings in block being faced with white metal, and there is a stuffing box at each end of the bearing, so that the rings work in an oil bath.

Outside diameter of rings	11½ inches.
Inside diameter of rings	9 inches.
Number of rings	9.
Thrust surface in square inches	362.27.
Length of condenser, total	8 feet 11 inches.
Diameter of shell	4 feet 6 inches.
Length of tubes (exposed)	7 feet 0 inches.
Diameter of tubes (outside)	⅝ inch.
Number of tubes (one condenser)	2,080.
Cooling surface (tubes, one condenser)	2,380 square feet.
Independent pumping engine, compound.	
Diameter of H. P. cylinder	11 inches.
Diameter of L. P. cylinder	18 inches.
Stroke (common)	12 inches.
Air pump (single acting) diameter	24 inches.
Air pump, stroke	12 inches.
Ratio of volume swept by L. P. piston per stroke to that swept by air pump piston per stroke	9.21 to 1.
Circulating pump (single acting) diameter	20 inches.
Circulating pump, stroke	12 inches.

Screw.—Type, modified Griffiths, adjustable blades. Material, manganese bronze.

Pitch, adjustable from 10 feet 6 inches to 14 feet 6 inches.	
Diameter	10 feet 6 inches.
Number of blades	3.
Pitch as set	12 feet 6 inches.
Helicoidal area	25.42 square feet.
Projected area	20.6 square feet.
Disc area	86.59 square feet.
Ratio of pitch to diameter	1.19
Greatest width of blade	2 feet 5½ inches.
Diameter of hub	2 feet 6½ inches.

Boilers.—There are four boilers of the low cylindrical type, each having three furnaces with a common combustion chamber. The boilers are placed in two separate water-tight compartments with air-tight fire rooms, the fire rooms being athwartships. There are two blowers in each fire room, drawing air from deck, and discharging directly into the fire rooms without the use of a blower casing or air duct.

The main and auxiliary feed pumps are of the vertical duplex type, and are placed in the fire rooms, one on each side on the coal bunker bulkheads.

There is one smoke pipe for the four boilers, the uptakes for each pair uniting above the water-tight bulkhead between the fire rooms.

The following are some of the dimensions of the boilers:

Length	17 feet 9 inches.
Diameter	9 feet 9 inches.
Number of furnaces in each (corrugated)	3.
Material of boilers	Steel.
Diameter of furnaces, maximum	41 inches.
Diameter of furnaces, minimum	37 inches.
Length of grate	5 feet 9 inches.
Outside diameter of tubes	2¼ inches.
Material of tubes	Iron.
Length of tubes between tube sheets	6 feet 11 inches.
Number of common tubes (one boiler)	370.
Thickness of common tubes	No. 11, B. W. G.
Number of stay tubes (one boiler)	68.
Thickness of stay tubes	No. 6, B. W. G.

Total number of tubes (one boiler)	438.
Depth of combustion chamber	45 inches.
Width of combustion chamber	8 feet 10 inches.
Height of combustion chamber above upper grates	20 inches.
Height of combustion chamber above lower grates	50 inches.
A hanging bridge wall is fitted in the combustion chambers.	
Thickness of shell plates	$\frac{11}{16}$ inch.
Thickness of tube sheets	$\frac{9}{16}$ inch.
Thickness of front head	$\frac{3}{4}$ inch.
Thickness of back head above tube sheet	$\frac{3}{4}$ inch.
Thickness of combustion chambers	$\frac{9}{16}$ inch.
Thickness of furnaces	$\frac{1}{2}$ inch.
Riveting: shell, longitudinal seams, double, with double butt straps.	
Riveting: shell, circumferential seams, double, with lap joints.	
Diameter of rivets	1 inch.
Diameter of fore-and-aft braces	2¼ inches.
Number of fore-and-aft braces	15.
Load on safety valves	160 lbs.
Boilers tested to	240 lbs.
Tube heating surface, one boiler	1,805.87 square feet.
Plate heating surface, one boiler	217.10 square feet.
Total heating surface, one boiler	2,022.97 square feet.
Grate surface, one boiler	55.0 square feet.
Area through tubes, one boiler	9.42 square feet.
Water surface, one boiler	146 square feet.
Steam room, one boiler	330 cubic feet.
Capacity of furnaces and combustion chambers above fire grates	204 cubic feet.
Weight of one boiler empty	27.5 tons.
Weight of water in one boiler	13.6 tons.
Weight of water and boiler	41.1 tons.
Diameter of smoke pipe	7 feet 0 inches.
Height of smoke pipe above lower grate	57 feet 6 inches.

Total for the Four Boilers.—

Grate surface	220 square feet.
Heating surface, tube, 7,223.48 square feet. Heating surface, plate, 868.40 square feet. } Total	8,091.88 square feet.
Area through tubes	37.68 square feet.
Capacity of furnaces and combustion chambers above fire grates	816 cubic feet.
Capacity of steam room	1,320 cubic feet.
Area of water surface	584 square feet.

Ratios.—

Tube H. S. to G. S.	32.83
Plate H. S. to G. S.	3.95

Total H. S. to G. S.	36.78 to 1.
Area through tubes to G. S.	1 to 5.8
Area of smoke pipe to G. S.	1 to 5.7
Water surface to G. S.	2.655 to 1.
Steam room to G. S.	6 to 1.
Capacity of furnace and combustion chambers to G. S.	3.71
Weight of boilers and water per 100 square feet of H. S. (in tons)	1.25
Fans, number	4
Diameter	4 feet 6 inches.
Type of fan engine, single cylinder, direct-acting, horizontal.	
Diameter of cylinder	7 inches.
Stroke of cylinder	4 inches.
There is a separator in the steam pipe from each pair of boilers.	
The total weight of machinery is (including water)	331.54 tons.
The total weight of boilers and water, with all fire room fittings	190.8 tons.

Performance.—The *Yorktown* left the shipyard of Wm. Cramp & Sons, at 9.31 A. M., February 12th, 1889, and anchored at Delaware Breakwater at 4.29 P. M., having made the run with natural draft and using all the boilers. Displacement at time of leaving the yard 1,720 tons, and at return 1,682 tons. As the armament and stores had not been supplied, 176.9 tons of pig iron were placed on board to represent them. There were 284 tons of anthracite coal in the bunkers, mixed in the proportion of three of egg size to one of broken; it burned freely, made no clinker, and but a small per cent. of refuse.

On February 13th, the vessel got under way and stood out to sea for the four-hour official trial which took place off Cape Henlopen. There was no trouble whatever with the machinery, and the boilers did not prime at any time. The blowers ran continuously during the four hours. Water was circulated through the bearings but was not used on any of them. Live steam was not admitted to the steam chests or receivers of the intermediate or low pressure engines. During the trial indicator cards were taken from each main cylinder at intervals of 15 minutes, and from the air and circulating pump engines every hour.

The speed was measured by two patent logs towed astern, and one chip log. The maximum speed before the wind was 17.2 knots and the minimum against the wind 14.9 knots, the mean

for the four hours being 16.14 knots. During the last hour of the run there was a head wind with a force of 7 on the Beaufort scale.

After the completion of the four-hour trial, turning circles were made as follows: at 10 knots speed, by rudder alone, time 5 min. 33 seconds. At 13 knots speed, one engine ahead and the other astern and the use of the rudder, time 5 min. and 53 seconds; and backing one engine and stopping the other, time 5 min. and 8 seconds. At 13 knots speed the starboard engine reversed in 7 seconds, and the port engine in 15 seconds; the vessel lost headway in 1 min. and 1 second, and had from 5 to 6 knots sternway in 1 min. and 58 seconds from the first signal.

At 3.30 P. M., the vessel started back to the shipyard, anchored over night at Reedy Island, and reached the yard at 10.13 A. M., February 14.

Draught of water at time of leaving the shipyard, forward, 13 ft. 4 ins.; aft, 15 ft. 4 ins.; mean, 14 ft. 4 ins. On return, forward, 12 ft. 8 ins.; aft, 15 ft. 6½ ins.; mean, 14 ft. 1½ ins.

SYNOPSIS OF STEAM TRIAL OF U. S. S. "YORKTOWN", FEBRUARY 13, 1889.

(AVERAGES.)

		Forward.	*Aft.*
Steam at boilers (per gauge)		151.	150.
		Starboard.	*Port.*
Steam at engines (per gauge)		142.3	144.8
Steam at 1st receiver (absolute)		68.7	72.7
Steam at 2d receiver (absolute)		20.6	19.7
Vacuum in condenser in inches of mercury		24.84	25.02
Revolutions of main engines		157.98	155.94
Piston speed in feet per minute		789.9	779.7
Throttle		Wide.	Wide.
Temperatures in degrees Fahrenheit	Engine room	71.	84.2
		Forward.	*Aft.*
	Fire room	58.7	72.5
		Starboard.	*Port.*
	Injection	40.4	40.4
	Discharge	97.2	88.
	Feed	91.0	102.6
Air pressure in fire room in inches of water		1.2	1.3
Revolutions of blowers		751.	763.
Revolutions of air pump engines		123.	120.5
H. P. Cylinder	Mean pressure	57.67	55.65
	I. H. P.	519.76	495.41

	Starboard.	*Port.*
I. P. Cylinder { Mean pressure	32.82	35.56
I. P. Cylinder { I. H. P.	588.78	631.89
L. P. Cylinder { Mean pressure	10.02	10.72
L. P. Cylinder { I. H. P.	471.16	498.28
Aggregate equivalent mean pressure on low pressure piston.	33.61	34.94
Collective I. H. P. (each main engine)	1,579.70	1,625.58
Collective I. H. P. (both main engines)	3,205.58	
I. H. P. of air and circulating pump engines	60.88	57.91
I. H. P. of blowers	52.03	
I. H. P. of feed pumps	16.15	
Aggregate collective I. H. P. of the main engines and auxiliaries	3,392.25	
Indicated thrust (I. H. P. of main engines only), lbs.	26,398.	27,521.
Indicated thrust per sq. ft. of developed area of propellers (25.42 sq. ft.) lbs	1,037.5	1,083.
Indicated thrust per sq. in. of thrust rings, lbs.	72.88	75.98
$\frac{S^3 \times \text{midship section}}{\text{I. H. P.}} =$	539.6	
$\frac{S^3 \times D^2}{\text{I. H. P.}} =$	176.75	
Speed	16.14	
Slip of propeller, per cent	17.19	16.07

The velocity of the steam through the ports at the maximum opening of the valves was, in feet per second—	*Outboard end.*	*Inboard end.*
H. P. steam port	115.85	160.45
H. P. exhaust port	90.66	90.66
I. P. steam port	200.5	146.0
I. P. exhaust port	104.6	104.6
L. P. steam port	225.1	165.2
L. P. exhaust port	122.1	122.1
Main steam pipe	98.12	
Main exhaust pipe	101.2	
I. H. P. per square foot of G. S.	15.42	
I. H. P. per ton of boilers, water and all fittings	16.72	
I. H. P. per ton of boilers, water and machinery	10.23	
Square feet of total H. S. per I. H. P.	2.385	
The steam has 25 seconds to dry in the boilers.		

	Starboard.	*Port.*
Cubic feet swept per I. H. P. per minute by the L. P. pistons	6.798	6.52
Ratio between the volume swept per minute by the L. P. piston in double strokes to that of the air pump piston in single strokes	27.8 to 1	28.01 to 1
Square feet of cooling surface per I. H. P.	1.503	1.464
Wetted surface by Kirk's analysis, square feet	10,498.	
I. H. P. per 100 square feet of wetted surface, at 16.14 knots	32.315	

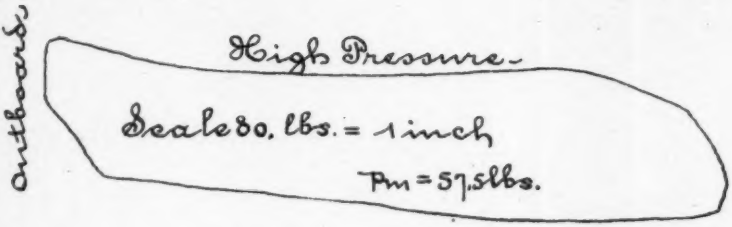
I. H. P. per 100 square feet of wetted surface, at 10 knots, reduced in ratio of 3.5 power	6.05

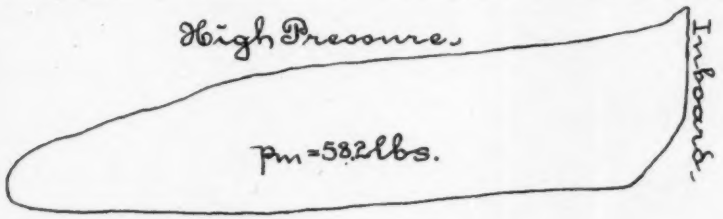
MAXIMUM.

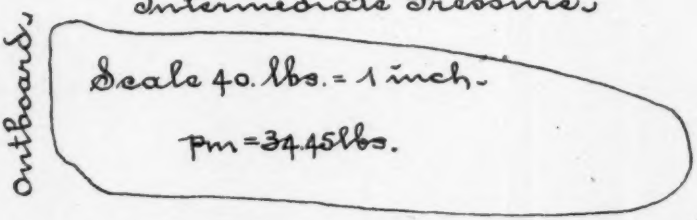
	Starboard.	*Port*
Steam at boilers (per gauge)	153.	159.
Steam at engines (per gauge)	148.	154.
Steam at 1st receiver (absolute)	70.	77.5
Steam at 2d receiver (absolute)	23.	20.2
Vacuum in inches of mercury	24.5	25.0
Throttle	Wide.	Wide.
Revolutions main engines	162.4	160.5
Piston speed in feet per minute	812.	802.5
I. H. P. of H. P. cylinder	535.60	528.20
I. H. P. of I. P. cylinder	655.45	694.30
I. H. P. of L. P. cylinder	528.25	568 40
I. H. P. aggregate each main engine	1,719.30	1.790.90
I. H. P. aggregate both main engines	3,510.20	
I. H. P. air and circulating pump engines	62.49	63.26
I. H. P. blowers	52.03	
I. H. P. feed pumps	16.15	
I. H. P. both main engines and auxiliaries	3.705.13	
	Forward.	*Aft.*
Air pressure in fire rooms in ins. of water	1.5	1.5
Cut off H. P. cylinder	0.77	
Cut off I. P. cylinder	0.766	
Cut off L. P. cylinder	0.766	
I. H. P. per square foot of grate surface	16.84	
I. H. P. per ton of boilers, water and all fittings	19.41	
I. H. P. per ton of boilers, water and all machinery	11.17	
Square feet of total H. S. per I. H. P.	2.184	
Steam used per I. H. P. in main engines, as shown by the indicator cards (not including condensation)	17.54 lbs.	
Cubic feet swept per I. H. P. per minute by the L. P. piston	6.42	6.09

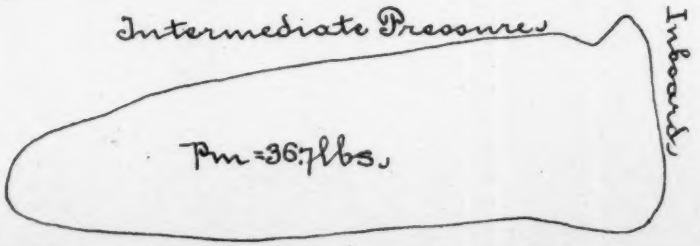
The indicator cards shown are for the maximum I. H. P., and the mean pressures have been corrected for errors in the indicator springs. It was impossible to weigh or even approximately estimate the amount of coal used during the trial. As the cylinders are not jacketed, the amount of steam condensed and not accounted for by the indicator cards is probably excessive.

Starboard

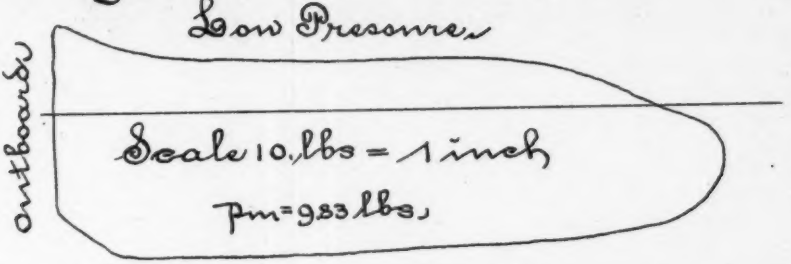

Outboard.
High Pressure.
Scale 80. lbs. = 1 inch
Pm = 57.5 lbs.

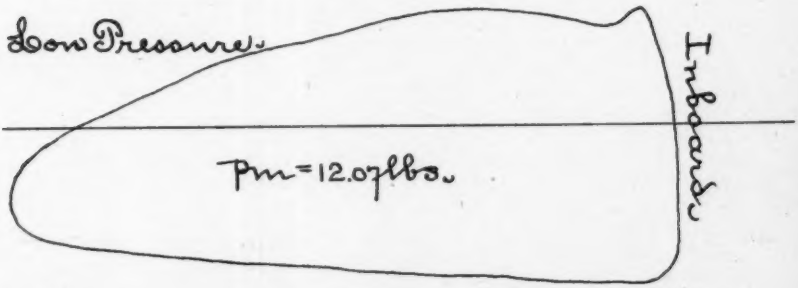

High Pressure.
Inboard.
Pm = 58.2 lbs.


Intermediate Pressure.
Outboard.
Scale 40. lbs. = 1 inch.
Pm = 34.45 lbs.

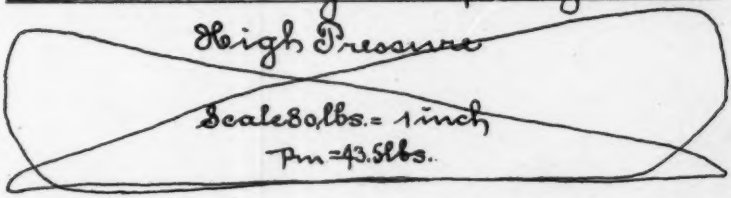

Intermediate Pressure.
Inboard.
Pm = 36.7 lbs.

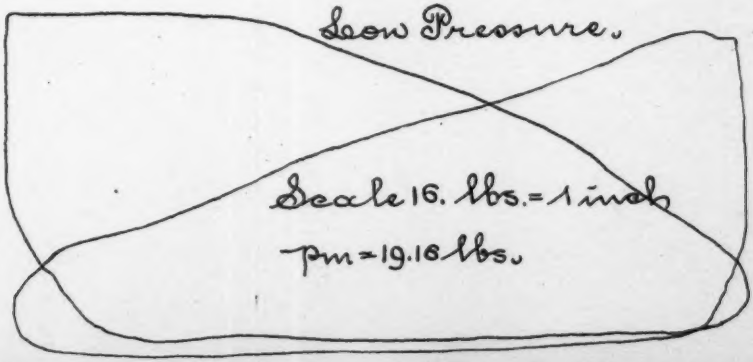
oard Engine.



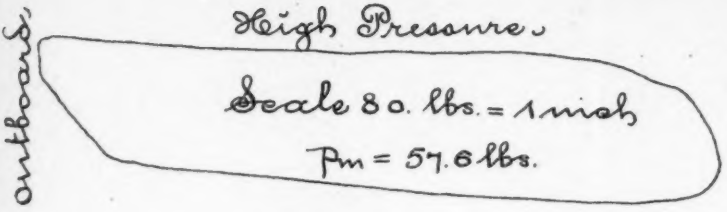


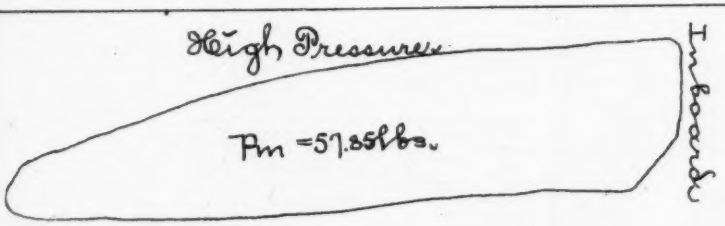
Air & Circulating Pump Engine.

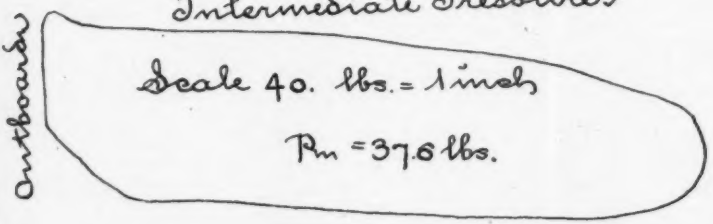


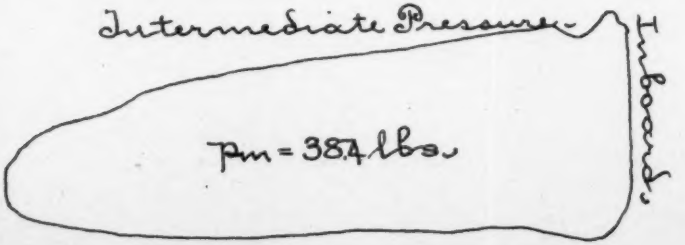


Port Eng


Outboard.
High Pressure.
Scale 80. lbs. = 1 inch
Pm = 57.6 lbs.


High Pressure.
Inboard.
Pm = 57.85 lbs.

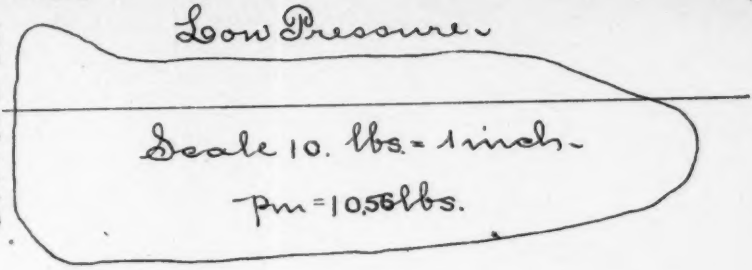

Intermediate Pressure.
Outboard.
Scale 40. lbs. = 1 inch
Pm = 37.6 lbs.


Intermediate Pressure.
Inboard.
Pm = 38.4 lbs.

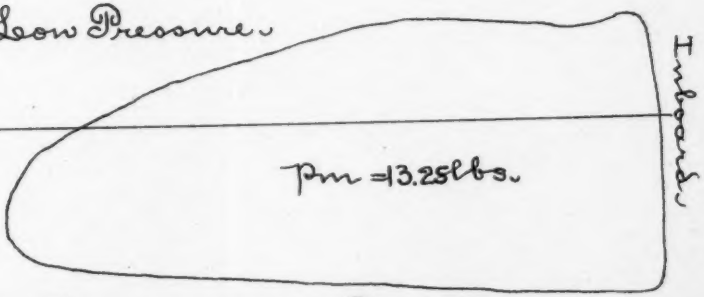
Engine.

Low Pressure.

Outboard.

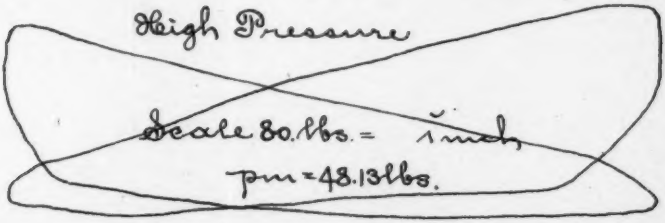


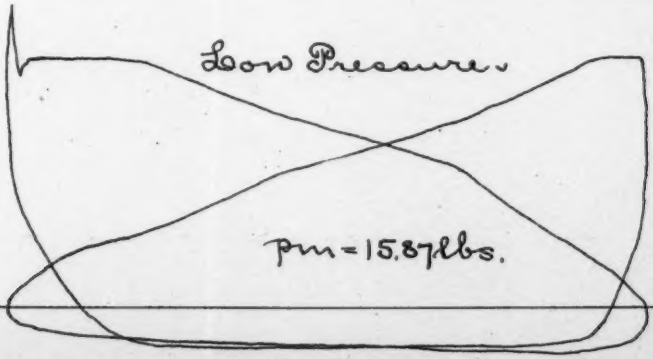
Low Pressure.

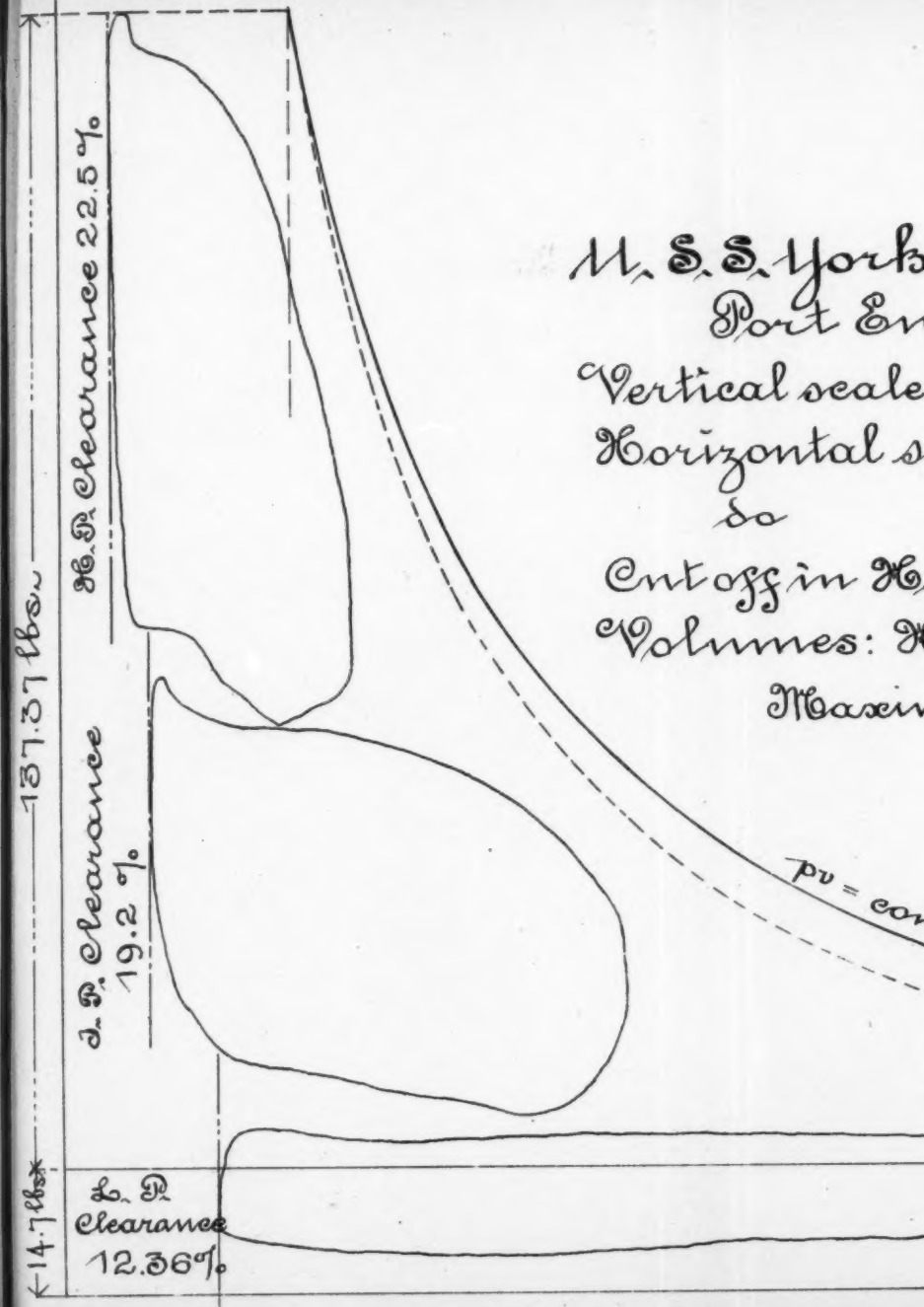


Air and Circulating Pump Engine.

High Pressure.







U. S. S. York
Port En
Vertical scale
Horizontal s
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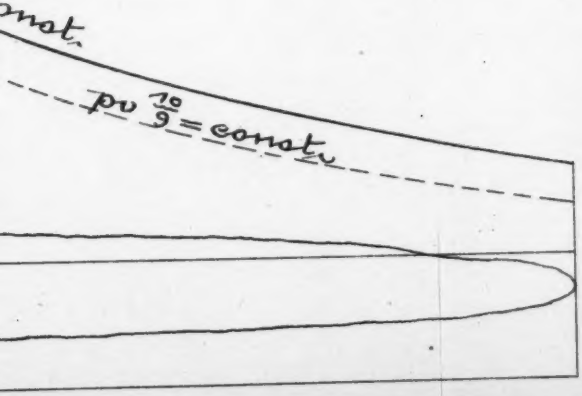
Cut off in H
Volumes: H
Maxim

stown
ngine
e 1 inch = 20 lbs.
scale 3 ins. = 1 foot
do 0.22065 ins. = 1 cubic foot
L.P. cylinder 0.75 stroke.
H.P. 6.504; I.P. 13.01; L.P. 33.99 cubic feet
mum I.H.P. 1791.90



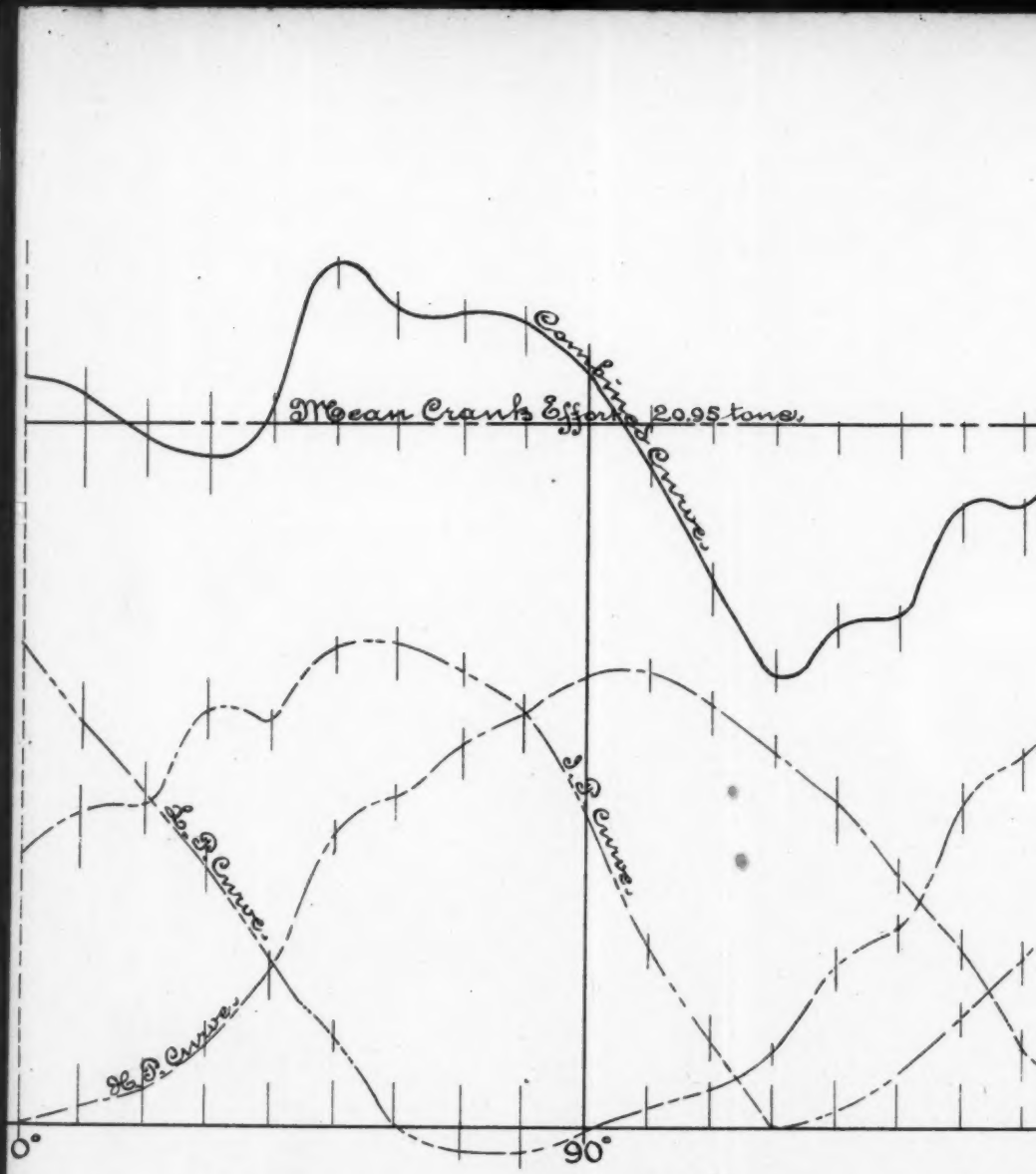
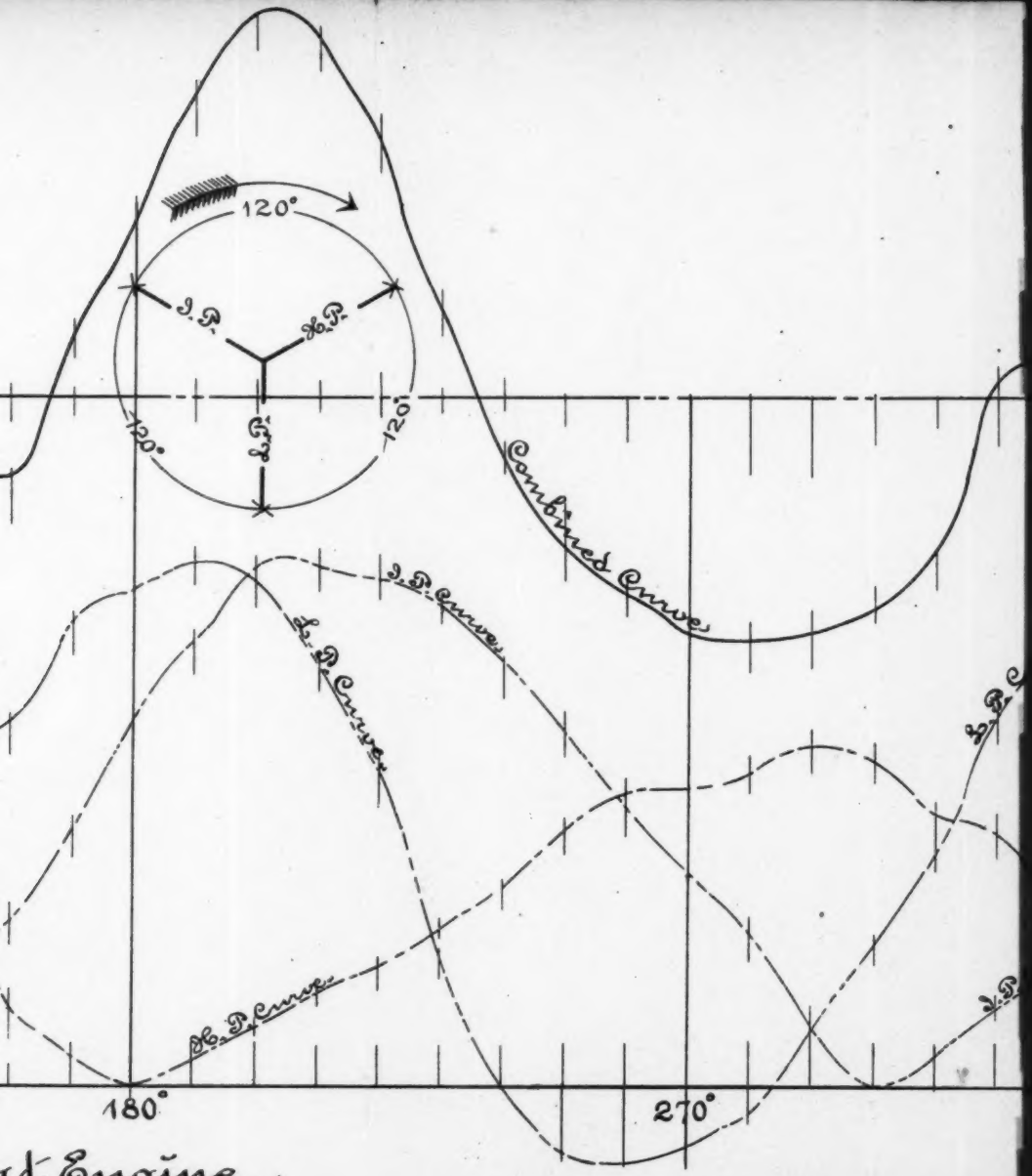


Diagram of Crank Effort. Por

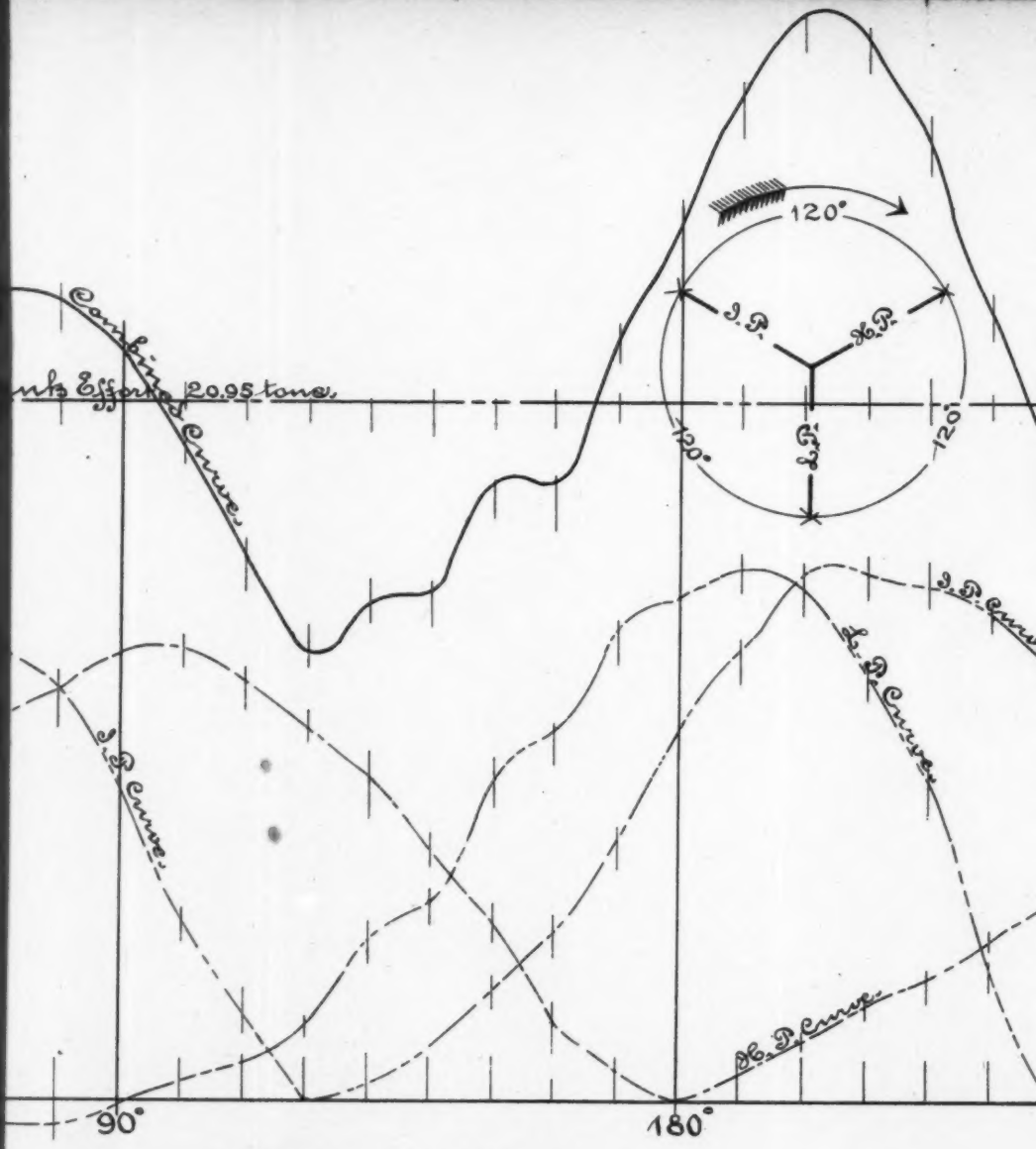
U.S.S. Yorktown



t Engine.

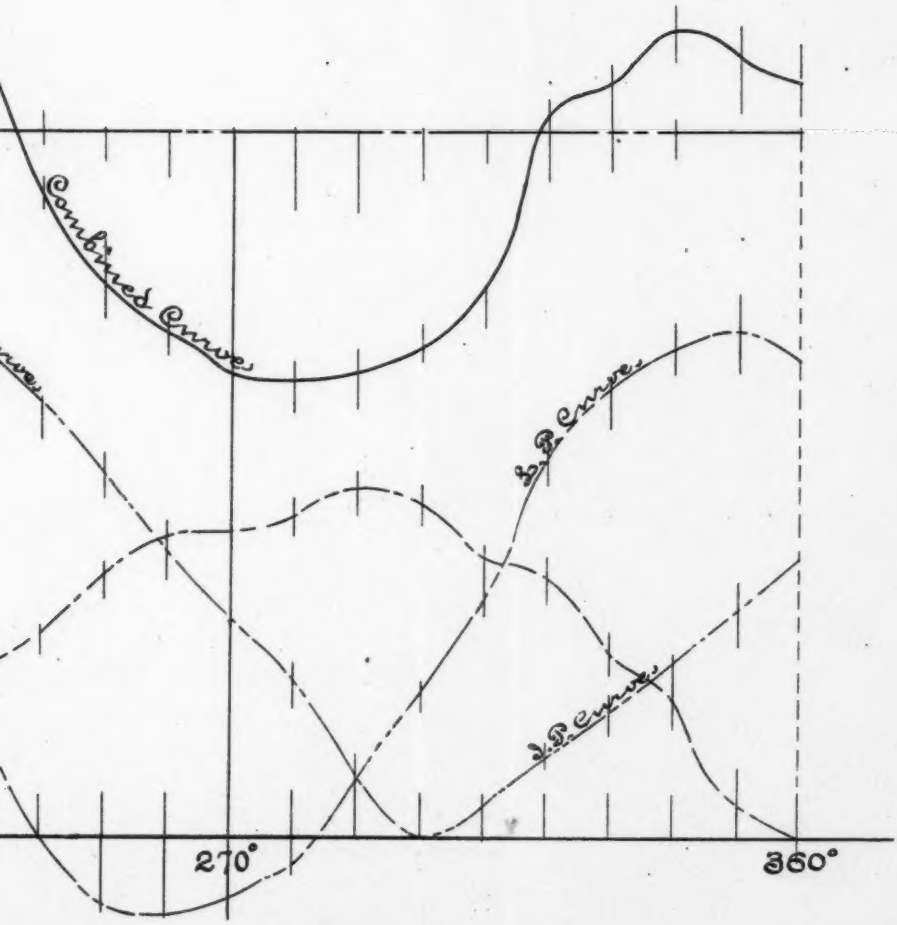
Maximum I.H.P. 1791.90

Vertical Scale 1 inch = 5 tons.



of Crank Effort ~ Port Engine ~

U. S. S. Yorktown ~



Maximum I.H.P. 1791.90

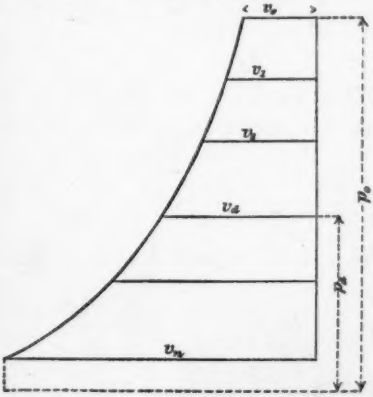
Vertical Scale 1 inch = 5 tons

XII.

FORMULA FOR THE DIAMETER OF CYLINDERS FOR SUCCESSIVE EXPANSION ENGINES.

By Assistant Engineer John L. Gow, U. S. Navy.

Suppose the expansion to take place in one cylinder of the volume of the L. P. cylinder with a card resulting as shown. In order to apportion this total work equally among several cylinders it is necessary to divide the above into any number of parts of equal area, and the volume of the resulting cylinders will then have the values represented by the lines $v_1, v_2, v_3 \ldots v_n$.



To deduce a general formula, let the number of cylinders be n, and d be any number in the series 1, 2, 3 . . . . n.

Let v_1, v_2 . . . . v_d . . . . v_n be the volume of the H. P., 1st I. P., 2d I. P. . . . . dth I. P. . . . and L. P. cylinders, respectively; p_1, p_2 . . . . p_d . . . . p_n the corresponding final pressures in such cylinders.

Let the equation of the curve be $pv^r = \text{constant}$. The total work, or area of the whole card will be

$$A = p_0 v_0 + \int_{v_0}^{v_n} p\,dv - p_n v_n, \qquad (1)$$

$$= (p_0 v_0 - p_n v_n) \frac{s}{s-1}. \qquad (2)$$

Similarly, the area below any line, as the dth, is

$$\left(\frac{n-d}{n}\right) A = (p_d v_d - p_n v_n) \frac{s}{s-1}. \qquad (3)$$

Eliminating A between (1) and (2)

$$\frac{n-d}{n} = \frac{p_d v_d - p_n v_n}{p_0 v_0 - p_n v_n}. \qquad (4)$$

Let r = total ratio of expansion $= \frac{v_n}{v_0}$.

Making this substitution and solving

$$v_d = \left(\frac{n}{(n-d) r^{s-1} + d}\right)^{\frac{1}{s-1}} v_n, \qquad (5)$$

or, as the volumes of the several cylinders are proportional to the squares of the diameters, the stroke being the same, the equation becomes

$$D_d = \left(\frac{n}{(n-d) r^{s-1} + d}\right)^{\frac{1}{2(s-1)}} D_n. \qquad (6)$$

The value of s is unity in hyperbolic expansion, and the equation becomes, after evaluating it,

$$D_d = \frac{D_n}{r^{\frac{n-d}{2n}}}.$$

The following comparisons have been made, however, by making $s = \frac{17}{16}$, as given by Rankine. Zeuner gives $s = 1.0646$. Using the value given by Rankine, equation (6) becomes

$$D_d = \left(\frac{n}{(n-d) r^{\frac{1}{16}} + d}\right)^{8} D_n. \qquad (7)$$

The equation is now in a form for determining the diameter of any cylinder in the series, having determined the size of the L. P. cylinder (D_n), and the total ratio of expansion r.

For compound engines $n = 2$, and $d = 1$; and making these substitutions in (7) we have

$$D_1 = \text{diam. of H. P. cyl.} = \left(\frac{2}{r^{\frac{1}{n}} + 1}\right)^s \times \text{diam. of L. P. cyl.} \quad (8)$$

For triple expansion engines $n = 3$, and d is successively 1 and 2; which being introduced into equation (7) gives

$$D_1 = \text{diam. H. P. cyl.} = \left(\frac{3}{2r^{\frac{1}{n}} + 1}\right)^s \times \text{diam. L. P. cyl.} \quad (9)$$

$$D_2 = \text{diam. of I. P. cyl.} = \left(\frac{3}{r^{\frac{1}{n}} + 2}\right)^s \times \text{diam. L. P. cyl.} \quad (10)$$

For quadruple expansion engines $n = 4$, and d is successively 1, 2, and 3; which being introduced successively in equation (7) gives

$$D_1 = \text{diam. H. P. cyl.} = \left(\frac{4}{3r^{\frac{1}{n}} + 1}\right)^s \times \text{diam. of L. P. cyl.} \quad (11)$$

$$D_2 = \text{diam. 1st I. P.} = \left(\frac{4}{2r^{\frac{1}{n}} + 2}\right)^s \times \text{diam of L. P. cyl.} \quad (12)$$

$$D_3 = \text{diam. 2d I. P.} = \left(\frac{4}{r^{\frac{1}{n}} + 3}\right)^s \times \text{diam. of L. P. cyl.} \quad (13)$$

In making the following comparisons I have assumed the diameters of the H. P. and L. P. cylinders of the following vessels, and computed the total ratio of expansion and the diameters of the intermediate cylinders. It will be noticed that the results as given by the formulæ agree very well with actual practice.

Compound Engines.

	H. P.	L. P.	Deduced value of r.	Boiler pressure.
Thames	37	63	6.77	110
Mersey	38	64	7.48	110
Scout	26	46	9.10	120
Brisk	27	50	10.75	120
Leopard	34	68	14.32	135
Tripoli	19½	35	16.77	130

Triple Expansion Engines.

	H. P.	L. P.	I. P.	Deduced value of r.	Boiler pressure.
Orlando	36	78	52.		130
Calculated			52.5	9.65	
Bramble	18½	43	29.		140
Calculated			27.9	11.79	
Rattlesnake	18½	42	27.		140
Calculated			27.6	11.03	
Ormuz	46	112	73.		150
Calculated			70.98	13.28	
Baltimore	42	94	60.		135
Calculated			62.2	15.74	
Newark	34	76	48.*		160
Calculated			50.2	10.54	
Philadelphia	38	88	56.*		160
Calculated			57.5	12.08	
Monadnock	19¼	52¾	30 75		160
Calculated			31.79	17.52	
Reina Regente	40	92	60.		140
Calculated			61.0	10.69	

*Subsequently changed to 52 and 58 respectively.

Quadruple Expansion Engines.

	H. P.	L. P.	1st I. P.	2d I. P.	Deduced value of r.	Boiler pressure.
County of York	20	57	28.5	40.		155
Calculated			27.9	39.6	15.43	
Grace Darling	10	28	14.	20.		200
Calculated			14.	19.6	14.73	
Myrtle	12	34	17.	24.		180
Calculated			16.7	23.7	15.19	
City of Venice	30	70	40.	52.		145
Calculated			39.4	52.3	9.22	
Suez	22	62	30.	43.		152
Calculated			30.7	43.3	14.92	
Jumna	35	94	48.5	67.		160
Calculated			48.	66.7	13.25	
Kronprinz, F'd Wm.	21½	61	30.5	43.		170
Calculated			30.	42.4	15.26	
Bromo	23	63	33.	43.		200
Calculated			31.7	44.3	14.01	
Lahora	24	68	34.	48.		160
Calculated			33.5	47.3	15.19	
Peking	23	67	35.	46.		
Calculated			32.3	46.1	16.39	

THE DEVELOPMENT OF THE MARINE ENGINE IN THE LAST DECADES.

Read before the Society of German Engineers in 1888, by CARL BUSLEY, ESQ., Engineer Corps, Imperial German Navy.

EXTRACTS MADE AND TRANSLATED BY ASST. ENGINEER F. C. BIEG, U. S. NAVY.

It is with great regret that the translator restricts himself, for want of time, to extracts from this valuable paper. Like all of Mr. Busley's works, it is exhaustive in its scope, excellent in the arrangement of its subject-matter, and well illustrated. The deductions drawn from the numerous sources consulted and studied are of interest and great value, coming from so high an authority as the author of the "Schiffsmaschine".

The author divides the subject of the advances made in the construction of marine machinery into the following heads and sub-heads. Under each sub-head, the experiments made and results obtained are sufficiently elaborated and the deductions drawn. The latter are given in the author's words as nearly as possible.

The divisions are as follows:

I. Improvements in the manner of using the steam.
   - *a.* The steam jacket.
   - *b.* The superheater.
   - *c.* The surface condenser.
   - *d.* The high-pressure engine.
   - *e.* The double-expansion engine.
   - *f.* The triple-expansion engine.
   - *g.* The quadruple-expansion engine.

II. Improvements in the manner of generating the steam.

h. Forced draft, by exhaust and by pressure.

i. Heating the air used for combustion.

k. Thorough heating of the feed water.

l. The use of distilled water to supply the waste in feed water.

m. Water tube boilers.

Under *a.* The value of the steam jacket decreases as the diameter of the cylinder, the piston speed and the volume of steam before cut-off increase; as the range of temperature in the cylinder decreases; as the supply of lubricant and air to the cylinder becomes more plentiful; as the temperature of the steam in the jacket is lowered; and, as the drainage of the water in the jacket is less frequent.

Under *b.* Long experience with superheaters and steam of low pressures, from 15 to 30 pounds per square inch, made it evident that in the long run it was not advisable to superheat the steam more than 70 or 46 degrees Fahrenheit, respectively, or up to 320°. As steam pressures rose, and consequently the temperatures, the margin left for superheating became gradually smaller, if the ill effects of too highly superheated steam on packings, lubricants, and the surfaces of the cylinders, valves and rods were to be prevented. The advantages of superheated steam being reduced to almost nothing, the superheaters were gradually dispensed with, and to-day none are built for high pressure boilers. Even steam driers are getting fewer, as slightly damp steam is preferred with high pressures on account of its help as a lubricant in the cylinders. The recent experiments of Normand, made at Harvre, France, to superheat the exhaust steam from the H. P. cylinder before its entry into the L. P. cylinder of compound engines, and also between the H. P. and I. P. cylinders, and between the I. P. and L. P. cylinders in triple-expansion engines, may also be characterized as failures. The steam from one cylinder was led through a superheater in the front combustion chamber into the next cylinder, its temperature having been raised by the heat of the gases of combustion. The complicated piping necessary to accomplish this prevented any further exten-

sion of this system, and the constant repair to the superheater pipes, in conjunction with the small gain obtained, led to the removal of these superheaters from nearly all steamers provided with them.

Under *c*. A wise economy in the use of lubricants in cylinders with high steam pressures is more strongly recommended where these lubricants, especially mineral oils, enter the boilers with the feed water, and give rise to the formation of harmful deposits.

Under *f*. The advantages of triple-expansion over compound engines lie mainly in the use of higher steam pressures, and in their better utilization, owing to the division of the expansion. From the numerous results of trials made, it appears that large well-designed triple-expansion engines, with boiler pressures of from 140 to 170 pounds per square inch, consume about 1.43 to 1.65 pounds of coal per I. H. P. per hour on trial trips. Expenditures of coal below 1.43 pounds may, in rare instances, occur when the fires are worked with especial care, when excellent qualities of coal are employed, and good boilers used which will give an evaporation of nearly nine pounds of water per pound of coal. These results should usually, however, be accepted with care. With boiler pressures of 200 pounds per square inch, the triple-expansion engine will, generally speaking, have reached the limit of its economic usefulness, as with this pressure, the range of temperature in each cylinder is already greater than 72° Fahrenheit.

Under *g*. The quadruple-expansion engines so far built have not yet shown their superiority over triple-expansion engines. Their substitution for triple-expansion engines has not been made a paying matter, for the simple reason that the range of temperature is too small for expansion in four cylinders. Only when initial pressures of about 225 pounds and over, with corresponding initial temperatures of about 392° F. and over, are used, will there be a chance for quadruple-expansion engines, in which the range of temperature must be at least 266° F., to show a real advantage over triple-expansion engines. That this advantage will be as great as that of the latter over compound engines can hardly be expected, in view of the following considerations:

First. The advantages of high over low pressures of steam—

that the same expenditure of coal will produce the same weight of steam, whatever its pressure; that the weight of unit volume of steam increases proportionately less as the pressure increases; and the power of greater expansion—become proportionately smaller the higher the pressure. The work done by one pound of steam of 300 lbs. initial pressure expanding, as in most engines, down to an absolute pressure of 7 pounds per square inch, is to that of steam of 180 pounds, about as 26 : 23; or, in other words, with a rise in pressure of 120 pounds, the theoretical gain in work is only about 11 per cent. In practice this amount is, of course, still further reduced.

Second. Although in quadruple-expansion engines, the loss due to condensation is smaller, on account of the decrease of the range of temperature in each cylinder, yet, on account of the friction of and cooling in the walls of the longer passages and the three receivers, this loss is greater than in triple-expansion engines of the same power. The saving in steam due to the expansion in four cylinders is, therefore, partly lost.

Third. It is a question, leaving out of consideration water tube boilers, whether the expected gain due to the use of steam pressures of 225 pounds and over will not be much too small, compared with the increased cost and weight of boilers as now constructed.

Fourth. Not only is the cost of boilers increased, but that of engines also, on account of patterns for four cylinders, four pistons, four valves, four valve chests and their covers, &c.

Fifth. The rise in temperature, following the increase in steam pressure, is an important point to consider. The temperature of steam of 75 pounds pressure is 320°, of 150 pounds, 365.9°, and of 300 pounds, 421.9° F. As the furnace sheets possess a somewhat higher temperature than the steam in the boiler, and as the steel of which they are made must be considered unreliable at a blue heat (corresponding to a temperature of about 473° F.), it is clear that with steam at 300 pounds pressure, the difference between its temperature and that at which the steel begins to be unreliable, is only about one-half that with 150 pounds, and only about one-third that with 75 pounds pressure.

Sixth. It is a question if the resistance and durability of the cast iron of the cylinders will not be less at temperatures greater than 392° F. than with those now used, and if, therefore, a limit to the working steam pressures will not be found in this direction.

Perhaps the above-mentioned difficulties will be overcome in time, as were those which were encountered when going from the low to the high pressure engine.

It would be rash to conclude that in the future higher steam pressures, with a corresponding increase in the number of steps in the expansion, cannot be adopted. In the present state of engineering science, however, there are various obstacles in the way of undertaking such constructions, as has been shown above; and besides, the gain to be expected from their use is, as yet, hardly tempting enough.

Under *h*. When the gases of combustion are either drawn or forced through the tubes, their temperature on leaving the smoke-pipe can be very much decreased. The heat thus saved can be utilized in the boiler by increasing the heating surface proportionately, or in the smoke-pipe, by means of heaters for the air for combustion or for the feed water.

The power required to produce artificial draft is, besides, so small, compared with the gain in the reduction of the temperature of the escaping gases, that to produce an air pressure of 1.2 inches of water in closed fire rooms there is chargeable to the blowers only about $\frac{3}{10}$ horse power for each square foot of grate surface. The comparative advantages and disadvantages of closed fire rooms and ashpits have repeatedly been the subject of extensive experiments and detailed discussion. If the facts and opinions thus brought to light are carefully balanced, the chief weight being given to the results of practical experience extending already over several years, the following conclusions will be reached.

With closed fire rooms no special precaution need be taken when opening the furnace doors, and the fire rooms are always well ventilated—a matter of special value when in the tropics. The chief disadvantages of this method are the inrush of con-

siderable quantities of cold air whenever the furnace doors are opened for coaling or working the fires; the poor ventilation, (which frequently exists when running with natural draft,) on account of the small number of openings in the decks; and the time necessary to hoist ashes, which is much greater than with open fire rooms, owing to the necessity of opening and closing the air-tight doors at both ends of the chutes.

With closed ashpits, the disadvantage of cold air entering the furnaces disappears, the amount of air entering when the doors are opened, and after equilibrium of air pressures has been restored, being even less than with natural draft. A special advantage is found in the fact that while cleaning one fire the others can be more strongly forced, thus preventing a fall in steam pressure and consequent reduction of revolutions. Again, the air can be heated before entering the furnaces, which cannot be done with closed fire rooms. Finally, the closed ashpits and the furnace doors can be made perfectly water-tight, as is done in the Yarrow torpedo boats recently built for Italy, so that in case of a large leak the fires can be kept going longer than with closed fire rooms. As against closed ashpits, it may be mentioned that, in the event of accident to the special locking arrangement, the furnace doors can be opened before the blast is shut off, in which case the pressure of air would force the flames and hot gases into the fire room and endanger the firemen. Further, owing to the separate attachments and air ducts for each furnace and the ventilating arrangements for the fire room, the installation of this system is more costly than a closed fire room.

The influence of the two systems on the steaming capacities of the boilers is almost the same, as is shown by Marshall's experiments. These experiments show also that the weight of water evaporated per hour increases with the air pressure, and that the efficiency of the boiler decreases as the evaporation is forced or increased. From this the conclusion has very often unjustly been drawn that the use of strong forced draft cannot be justified on economic grounds. The decrease in the efficiency of the boiler is due only to the smallness of the heating surface relatively to the amount of coal burned, on account of which the

greater quantity of heat generated cannot be utilized. The boilers of recent warships are not designed with the greater heating surface which is necessary for a perfect utilization of the heat of the gases of combustion when strong forced draft is used, because, as these ships usually steam at very much reduced speeds, it is not profitable to carry around the extra weight of the larger boilers. To save in displacement, it is, therefore, considered preferable to burn a few extra tons of coal in those rarely occurring cases when full power is used. This waste of coal can never be very great, as experience has shown that it is impossible to steam continuously for more than ten or twelve hours with strong forced draft, as even when using the best coal the grates become so choked with clinker that it is absolutely necessary to clean the fires.

Carefully and strongly built boilers, attended by well trained firemen, and working usually with moderate forced draft (1 to 1.2 inches of water,) and only exceptionally with strong forced draft, will last as long and require no more repairs, even if used continuously with forced draft, than if natural draft only is used.

The economic advantages which may be realized by the use of forced over natural draft are explained by the more intimate combination of the plentiful supply of air, which penetrates all pores and holes of the layer of fuel, with the combustible gases generated in this layer, whereby a more nearly perfect combustion is assured.

The heating surface of boilers usual in the merchant marine ranges from 27 to 30 times the grate surface, and when strong forced draft is to be used this ratio is increased to 40 and 50, by reducing the grate surface, and, with moderate forced draft, as high as 60.

Therefore, by the use of moderate forced draft, which makes a more complete combustion possible, a more advantageous utilization of the fuel is secured, and by the increase in the heating surface, a greater transfer of heat from the gases of combustion to the water takes place. If to these be added the advantages of

heating the air for combustion or the feed water, a noticeable saving of coal is possible.

Under *i*. The economic advantages which may be gained by heating the air before it enters the furnaces, are shown by the results of actual trial on three steamers fitted with Howden's, and on one steamer fitted with Wylie's arrangement. To these results must be added those of the extensive experiments made by Hoadly in America and Spence in England.

Regarding the results of trials with Howden's arrangement, it appears to me (Mr. Busley) that the same saving of coal would be affected if Howden's objectionable heater were omitted and only his system of moderate forced draft, which gives a proper distribution of air above and below the grates, retained.

By the published results of the tests of Howden, Hoadley and Spence, it is proved that a certain, although small, advantage may be gained by heating the air used for combustion. Spence is the only one who has determined the saving in coal for an increase of about 180° F. in the temperature of the air, which, in the case of boilers of construction and location similar to marine boilers, he places at about 4 per cent. Hoadley, however, estimates an economy of from 10 to 15 per cent. with boilers which are bricked in and when the temperature of the air is raised to about 320° F. From this amount the saving due to the use of forced draft is to be deducted.

It is apparent, therefore, that heating the air will tend to economy only when the heat used for this purpose is obtained from the escaping products of combustion and not from an extra supply of coal; and further, when the heater, with a low first cost and small expense of maintenance, is so efficient that the temperature of the air is raised at least 180° F.

Under *k*. The first attempts to heat the feed water after it leaves the condenser were those of Weir and Mac Laine, and were aimed chiefly at prolonging the life of the boilers, while the recent ones of Howden and Kemp seek to obtain a saving of coal in addition. Although the widely known trials of these heaters furnish results which, in part, are untrustworthy and very incomplete, still

they show that it is more profitable to utilize the heat of the gases escaping from boilers working with forced draft, (either exhaust or pressure,) in heating the feed water than in heating the air used for combustion.

Under *l.* Experience so far shows that it has become a necessity, for the preservation and economic use of boilers working under high pressures, to make up the waste in feed by distilled water.

Under *m.* Against the advantages of reduced weight and increased pressures, possible with water tube boilers, must be set the disadvantages of small water surface and poorer circulation which are found in nearly all of these boilers.

The Thornycroft boiler is especially suited for the production of splendid results on trial trips. Should this boiler work in service as well as it is said to have done on trial trips, it would mark a very noteworthy advance in the construction of water tube boilers for ship use; and, as it approaches perfection, it is not improbable that it will displace locomotive boilers from torpedo boats.

From experience with the Belleville boiler in the French navy it seems that it has not entirely reached the useful capabilities of the ordinary cylindrical boiler. For want of results of more extended experiments and observations, it cannot be decided whether this is or is not due to the peculiar arrangement of the steam collector, which, serving at the same time as a feed water heater and purifier, causes a very considerable drop in the steam pressure between the boiler and steam pipe. Fault is also found with these boilers on account of their unsuitability for heavy firing with natural draft, although they gave satisfactory results in this respect on the despatch boat *Milan*. It is said that with rapid rates of combustion there is always imminent danger from priming and from the gases of combustion, which, as their passage is rather unrestricted by the tubes, leave the smoke-pipe in long bright flames. This is in general, the same objection that Isherwood found to the Perkins boiler, and the cause of which he refers to the small surface of the water from

which the steam must escape. These boilers work to most advantage with a low, and to least advantage, with a high rate of evaporation. Finally, the uninterrupted working of the Belleville boilers depends chiefly on the action of the very complicated, automatic feed arrangement. This is a constant source of care, although with conscientious attention it has so far always worked satisfactorily. But considering the very important improvements which have been made in the construction of this boiler since the introduction of the first one in 1866, it is reasonable to suppose that these objections will be overcome.

Should it, therefore, happen, as now seems probable, that at no distant day a water-tube boiler will be built to meet all requirements of marine service, the greatest obstacle to a considerable increase in steam pressures—disproportionate increase in weight and cost of boilers—will no longer exist.

FINAL REMARKS.

If the successes attained in marine engineering in the last few decades are reviewed as a whole, the advances which have been made in the construction of the machinery must be added to the improvements made in the production and manner of using steam. These have caused—

1. A decrease in the weight of the machinery.
2. A reduction of the internal resistance of the machinery.
3. An increase in the speed of the ship.

Under 1. This has been accomplished by the substitution of stronger and lighter materials and by a more careful design of all the component parts of the machinery. The result, taking into account the increased piston speed, has been the almost incredible reduction in the weight of screw engines, including boilers with water, propellers, &c., from about 550 pounds, the weight about the middle of the fifties, to about 55 pounds per I. H. P., the weight of the latest torpedo boat engines.

Under 2. This was sought for in the use of independent pumps, the employment of packings and bearings of less friction, the

substitution of good and simple balancing arrangements for the valves, and, finally, in careful fitting of the machinery in the shop and its accurate erection in the ship. How successful these endeavors have been, may be seen from the fact that the old screw engines utilized only about 35 per cent. of the I. H. P. in propelling the ship, while in the case of the more recent, large and fast steamers, this figure reaches almost 55 per cent., and in the latest torpedo boats, more than 60 per cent. Regarding the careful fitting in the shop, it may be remarked that at the works of the Central Marine Engineering Co. of West Hartlepool, of which the well known Mr. Mudd is the director, the machinery is not only erected in the shop, but also tried under steam. This has been done in the case of all marine machinery built in the last few years. From published indicator diagrams of four sets of triple-expansion engines, it was found that the I. H. P. necessary to run the engines unloaded, but including the friction of the slightly loaded pumps, was only about 6 to 7 per cent. of the I. H. P. which was afterwards realized on the full power trials, while generally this amount has been taken at 13 per cent.

Under 3. Aside from the employment of finer and narrower hulls, this is chiefly due to the progress which has been made in the design, construction and location of the propellers, the fruit of numerous experiments with ships and boats, and of years of experience with steamers. But, of course, the improvements in the construction of the machinery and the reduction of its weight have also helped to increase the speed. While a speed of 14 knots over the measured mile was considered an extraordinary performance in the fifties, some of the latest mail and naval steamers have even surpassed a speed of 20 knots under the same conditions. For instance, the Spanish cruiser *Reina Regente*, has reached a speed of 20.13 knots, and the Cunard steamers *Umbria* and *Etruria*, 20.18 knots.

The very decided superiority of the marine engine of to-day over that of about thirty years ago, is clearly shown by the

following comparison, which in round numbers gives average values.

Type of engine.	Steam pressure in boilers, in lbs. per sq. in.	I. H. P. per sq. ft. of grate surface.	I. H. P. per pound of steam per second.	Pounds of coal per I. H. P. per hour.	Daily consumption of coal per 1,000 I. H. P., in tons.*	Weight, in lbs., of the complete machinery, including water, per I. H. P.	Power utilized in propelling the ship, in per cent. of the total power developed.	Greatest speed attained by ocean steamers, in knots per hour.
Watt's low-pressure engine of 30 years ago....	19	5	80	5.5	60	550	35	14
Triple-expansion engine of to-day, with the latest improvements.....	170	20	270	1.32	16	200*a*	55*b*	20*c*

* At 2,000 pounds. (Transl.)

a The weight of machinery in the latest torpedo cruisers is only about 90 to 110 lbs., and in torpedo boats, about 55 to 66 lbs. per maximum I. H. P.

b With carefully built torpedo boat engines, about 60 per cent. of their indicated power is now utilized in propulsion.

c The fastest torpedo boats, finished in the spring of 1887, made between 25 and 26 knots on the measured mile and lightly loaded, while five of the torpedo boats which Schichau is now building for the Italian Navy, are to develop a speed of 27 knots. The fastest ocean screw steamers mentioned above reached 20.13 and 20.18 knots, and the fastest paddle-wheel steamers, the "Queen Victoria" and "Prince of Wales," tried in 1887, reached 22.6 and 24.25 knots respectively.

METHOD OF DETECTING ADULTERATIONS IN OLIVE OIL.

Consul Frank H. Mason, at Marseilles, under date of July 31, 1888, gives the following on the methods of detecting adulterations in olive oil:

As late as the 17th of May last a meeting of the Scientific and Industrial Society of Marseilles was addressed by M. Ernest Millian, an accomplished analytical chemist, who reviewed elaborately all of the known processes, and admitted that none of them were sufficiently delicate and exact to detect an adulteration of less than 10 per cent. The "Cailletet" process, which consists

in treating the oil with a mixture of sulphuric and nitric acids, has been hitherto generally employed, but this was declared by Mr. Millian untrustworthy unless the degree of adulteration exceeded 20 per cent.

The "Bechi" process, now used by the Italian Government, will detect an admixture of 15 per cent. of cotton-seed oil, provided the sample analyzed contains no glycerine, formic acid, or free fatty acids, any one of which, even in minute quantity, is sufficient to mask the chemical reaction upon which the process of Signor Bechi depends.

M. Millian then described a new method, invented by himself, which consists in treating with heat the saponified products of the oil in alcoholic solution with nitrate of silver. This, however, is a process for the laboratory of the accomplished chemist, and is not adapted to general use. The same is true of the "Levallois" process, which has been used by experts in cases of real importance with more or less questionable results, the analysis in one notable instance having given the same result from a sample of pure olive oil and another which was known to contain 20 per cent. of cotton-seed.

Finally, as it would seem, the long-sought-for process has been discovered by M. Brullé, chemist of the Agronomic Station at Nice. His discovery was announced to the Academy of Sciences in April last and has been since subjected to an elaborate series of tests and experiments by a commission specially appointed for the purpose by the Agricultural Society of the Alpes-Maritimes.

M. Brullé began upon the known principle that vegetable oils, when oxydized by the application of certain acids, assume different shades of color. He then hit upon the use of albumen to fix and accentuate these delicate gradations of tint. The report of the commission has recently been published and gives the process of M. Brullé such complete and unqualified endorsement, both for its simplicity and the exactness of its results, that the subject assumes a practical importance not only to the countries which produce olive oils, but to those which, like our own, import them as costly luxuries for general consumption.

In its series of experiments at Nice the commission first applied

the process of M. Brullé to six classes of samples, viz., first, to pure olive oil, then to the same oil with an admixture of 5, 10, 20 and 50 per cent., respectively, of cotton-seed oil, and, finally, to the pure cotton-seed oil itself. When the result had been established by repeated experiments with each grade of samples, a *fac simile* of the tint produced by each successive degree of adulteration was prepared by dissolving certain aquarelle pigments in stated quantities of water. Thus the process and a standard system of proofs was put within reach of any person having a good eye for color and a slight familiarity with chemical manipulations.

The process of M. Brullé is as follows: Put into a test tube 1½ grains of pure albumen (this should be gently heated in the flame of an alcohol lamp to expel any remaining moisture in the albumen which might otherwise modify the exactness of the result), then add 3 cubic centimeters of nitric acid and 10 cubic centimeters of the oil to be tested (the quantity of each ingredient used is, of course, immaterial, provided the above relative proportions are maintained; a test tube graduated metrically is the most convenient for the purpose); the mouth of the tube is then closed with a cork to prevent the boiling over of the liquid during ebullition, but pierced with a small orifice to permit the escape of vapor, which would otherwise explode the tube. The materials are mixed by shaking, but the nitric acid quickly settles to the bottom. Now warm gently in the lamp the part of the tube containing the oil, then apply the flame to the underlying stratum of acid. A fierce ebullition soon ensues, and when this is at its height plunge the tube into ice water sufficiently cold to chill the contents to 4° centigrade, or its equivalent, 39.2° Fahrenheit. During the cooling process there is developed an oleaginous precipitate, ranging in color from pale yellow to reddish-brown, according to the proportion of cotton oil contained in the tested sample. The experiment requires only the simple apparatus above mentioned, and occupies only four or five minutes.

The findings of the commission at Nice are tabulated in its official report, as follows: The standard tint in each grade being

produced by dissolving the stated number of units of each pigment named in 100 units of water. For this purpose ordinary dry cake water-colors are most convenient.

1. Pure olive oil yields a precipitate tinged like 5 units of Naples yellow dissolved in 100 units of water.

2. Olive oil containing 5 per cent. of cotton oil yields the tint of 5 units Naples yellow and 5 units of dark chrome yellow in 100 units of water.

3. Olive oil containing 10 per cent. cotton seed yields a tint equal to 20 units Naples yellow, 6½ units chrome yellow, and 1 unit Chinese vermilion, in 100 units of water.

4. Olive oil containing 20 per cent. cotton seed yields a tint equal to 6½ units Naples yellow, 6 units chrome yellow, and 1½ units Chinese vermilion, similarly dissolved.

5. Olive oil with 50 per cent. cotton oil yields a tint equal to 5 units Naples yellow, 5 units chrome yellow, and 5 units of vermilion.

6. Pure cotton oil yields a precipitate having the color of 3½ units chrome yellow, 10 units of vermilion, 1 unit of burnt sienna, and 1 of natural sepia, in 100 units of water.

Other seed oils, including sesame, cameline, peanut and poppy seed give a precisely similar series of tints in proportion to the degree of their admixture with olive oil, except that the colors are more inclined to the reddish shade, which would be produced by covering the corresponding cotton seed tint with a thin wash of carmine.

These gradations of color are most marked when the liquid in the tube is at about the stated temperature, 39.2° F. As the precipitate is further chilled to the freezing point, the colors fade and lose their individuality.

Such is the system which it is now expected will enable purchasers and consumers of olive oil in this country to detect the adulterations, which have become so general that very few brands or firm names are any longer a guaranty of purity. When it is remembered that more than 2,000,000 gallons of cotton seed oil are exported from the United States to Marseilles in a single year, and that more than half of this vast quantity is used for adulterating olive oils, a large part of which are re-imported to the United States through a 30 per cent. duty, the importance of some new and better means of controlling the integrity of this trade will be apparent.

SOME RECENT MERCHANT STEAMERS.

The most important addition made to the list of ocean greyhounds during the last year is the *City of New York*, built by Messrs. J. & G. Thomson, Clydebank, Scotland, for the International (Inman) Steamship Company. She was built to make the trip in less than six days, but her machinery gave so much trouble that she proved a great disappointment, and was laid up last autumn, after four voyages, for a general overhauling. Although much reticence is observed as to the trouble with her machinery, it may be confidently stated that the principal cause of the failure to get the speed expected was due to the boilers, which primed when forced to the power required, although the piston valves and circulating pumps also gave trouble.

She is 525 feet long on the water line, 560 feet over all, 63¼ beam and 42 deep (moulded), her tonnage being 10,500; the displacement on a draught of 26 feet is stated to be about 12,000 tons. She is divided into fifteen water-tight compartments, has a double bottom and is fitted with rolling tanks. Her rudder is on the well-known Biles patent, which is practically the same as that designed for the Stevens Battery; it is operated by hydraulic power.

The engines are twin-screw, triple-expansion, each set in a separate water-tight compartment, a central longitudinal bulkhead separating the engine rooms. The cylinders are 45, 71 and 113 inches in diameter by 5 feet stroke, supported on cast-steel frames weighing six tons each, or twelve tons for each cylinder. The steam valves are all of the piston type, there being one for the high, two for the intermediate, and four for the low pressure cylinder, all worked by the Stephenson double-bar link motion. The crank-shaft, which is made in interchangeable sections, is 20¼ inches in diameter, and the pins 21 inches; the line shafting is 19¼ and the propeller shaft 20¼ inches, with an 8-inch hole through it—all made of steel. The crank-shaft and pins and the line-shaft have 4-inch axial holes through them. The thrust is taken by 11 horseshoe collars of cast-iron lined with white metal. The original screws were three-bladed, 22 feet diameter and 28 feet pitch; but, although they gave good results in heavy weather, they were not believed to be "record" break-

ers, and smaller ones were substituted during the time she was laid up.

The boilers are nine in number, divided into three groups, each group placed in a separate water-tight compartment. They are double ended with three furnaces at each end, and were designed for a working pressure of 150 pounds; they are worked on the closed stokehold system of forced draft, twelve fans 66 inches diameter being used for this purpose, maintaining an air pressure equal to about ¾ inch of water. The grate bars run transversely, and are of the shaking pattern, operated from the fire room. The following are the principal data: Diameter, 15 feet 6 inches; length, 19 feet; diameter of furnaces, 47 inches; number of tubes, 1,056—diameter, 2⅜ inches; thickness of shell plates, $1\frac{9}{32}$ inches; weight of each boiler, 74 tons. The total grate surface is 1,293 and the heating surface 50,265 square feet. The feed pumps are of the Worthington pattern.

She has two evaporators, each capable of supplying 40 tons of fresh water a day. Tangye's centrifugal circulating pumps and engines were used on her, but Gwynne's have been substituted in the *City of Paris*. On her trial trip, she is reported to have made 17.5 knots for 46 hours on from 82 to 83 revolutions, and to have developed about 18,000 I. H. P.

In the *City of Paris*, a sister ship, the builders profited by their experience with the *City of New York*, as she completed her first westward voyage on the 11th of April, making a good first passage of 6 days 18 hours and 53 minutes, although she ran under one engine for five hours, owing to trouble with piston rod packing. The return voyage was made in 6 days 5 hours and 55 minutes. On her third voyage, which was completed on the 8th of May, she broke the record, making the run of 2,855 miles in 5 days 23 hours and 7 minutes. On three successive days she made 504, 505 and 511 miles respectively, the running time being 44, 43 and 45 minutes in excess of 24 hours. The average revolutions were 88 per minute.

Both of these vessels are on the British Admiralty list of auxiliary cruisers.

The White Star Line has two steamers under way, the *Teutonic* and the *Majestic*, the first of which will soon be ready for service. They are building by Harland & Wolff, Belfast, Ireland, and, like the Inman steamers, have twin-screws, and are fitted in the most approved manner for passenger traffic. They are 582 feet over all, 57 feet 6 inches beam, 39 feet 4 inches deep, and of about 10,000 tons, provided with double bottoms, and numerous water-tight compartments.

The engines, each set in a separate water-tight compartment, are triple-expansion, with cylinders 45, 68 and 110 inches in diameter, by 5 feet stroke, working with a boiler pressure of 180 pounds. The boilers are divided into two groups, placed in water-tight compartments, and are designed to work on Howden's closed ashpit system of forced draft.

One of the features in these vessels is the method of placing the screws. They are not in line athwartships, one screw being placed about 10 feet abaft the other, the "deadwood" being cut away so that the disc of one screw overlaps that of the other.

These steamers are expected to make the trip across the Atlantic in six days. Both are on the British Admiralty list of auxiliary cruisers, each being fitted for mounting twelve guns.

Another steamer building for the trans-Atlantic trade is the *Columbia*, building by Laird Bros., of Birkenhead, for the Hamburg-American Packet Co. She is 463 feet long, 56 beam, 36 deep, and of about 7,000 tons, her displacement on a draught of 24 feet being 10,000 tons. She has three masts, and carries fore-and-aft sail only. Like the others described, she has twin-screws, and is divided by eleven transverse water-tight bulkheads, and a central longitudinal one between the engine-rooms, besides having a double bottom running the full length of the ship. Her engines are triple-expansion—cylinders 41, 60 and 101 inches diameter, by 66 inches stroke—designed for 12,500 horse-power. There are nine double ended boilers, in three separate compartments, working at a pressure of 150 pounds per square inch.

The *Alfonso XIII* and the *Reina Maria Christina*, two steamers built by Denny Bros., Dumbarton, Scotland, for the Compania Transatlantica, of Barcelona, are the latest additions to the list of Spanish auxiliary cruisers, being fitted for mounting eight guns. They have four masts, and are of the following moulded dimensions: 400 by 48 by 32, and 5,060 tons gross register.

The engines are single-screw, triple-expansion—cylinders, 34, 57 and 91 inches diameter by 5 feet stroke, supplied with steam, at 170 pounds pressure, from three double ended boilers, fitted for working on the closed ashpit system of forced draft. To avoid large copper pipes, the steam from boilers to engines is led through two pipes. The crank-shafts are 17½ inches in diameter, and are made in interchangeable sections. Coal protection for engine and boilers is provided on the sides, as in the case of protected cruisers.

On trial, the *Alfonso XIII* made 16.8 knots with natural draft, and 17.3 with forced draft, each trial being of six hours' duration. The *Reina*, under similar conditions, made one-tenth of a knot more.

Another vessel for the same company, and of the same dimensions, the *Alfonso XII*, built last year by Wigham, Richardson & Co., Newcastle-upon-Tyne, is also on the list of Spanish auxiliary cruisers.

THE ENGLISH NAVAL MANŒUVRES OF 1888.

The reports of the Admirals commanding the squadrons engaged in these manœuvres were submitted to a committee consisting of two Admirals and a Vice-Admiral, with instructions to report generally on the lessons to be learned, and especially on the value of torpedo gun-boats, the behavior, sea-going qualities and defects in new vessels, and the recommendations to improve them.

"Extracts from the report of the Committee" have been published, giving in detail the operations of each squadron and of each vessel engaged, with the conclusions of the committee, as required in the instructions. The report goes far toward emphasizing the oft-repeated charge that the overpowering of small vessels, necessitating a reduction in weight of machinery far below that necessary to withstand the strain under the actual conditions of service, is disastrous in the extreme. Vessels with a reputed speed of 16 and 17 knots appeared to be doing well when they made 14 without mishap, and there seems to have been a general want of confidence in the ships to steam in an emergency, to say nothing of the effects on the hull when running the engines at full power.

The Committee reports as follows, regarding torpedo craft:

"Torpedo gun-boats of high speed and *good coal capacity* would be of incalculable value to the blockading fleet, but torpedo-boats of any class at present in use would be of far more value to the blockaded squadron than to the blockaders.

"Torpedo-boats, if not capable of keeping the sea independently *under all conditions of weather*, would invariably prove a cause of embarrassment and anxiety to an Admiral commanding a blockading fleet, and would be subject to endless casualties.

"The employment of torpedo-boats as an inner line of blockade is not desirable, they being calculated to cause much confusion and embarrassment to their friends. They should not be used as despatch-vessels, or for any purpose other than that for which they are designed."

It will be observed that the conditions laid down as being absolutely necessary in torpedo gun-boats and torpedo-boats are those which do not exist in any at present built or contemplated. The coal capacity of the torpedo gun-boats engaged in the manœuvres was only 80 tons, not enough for two days' steaming at full power, while the absence of sea-going qualities in the torpedo-boats was fully shown by the extracts from English service journals given in the first number of the JOURNAL.

Under the head of general criticisms of new ships, the ships are taken by types, and only the more important defects are noticed, but the opinion of the committee is that all of the cruiser type are too heavily armed.

The following are the observations on each type:

Rodney, Benbow, Collingwood. [Armored battle-ships of the *Admiral* class. *Rodney:* Length b. p., 325; beam, 68; mean draught, 27 feet 10½ inches; displacement, 10,300 tons. Corresponding dimensions of *Benbow*, 325 by 68½, by 27 feet 10 inches, and 10,600 tons; of *Collingwood*, 325 by 68, by 26 feet 10½ inches, and 9,500 tons. The *Rodney* mounts four 69-ton, six 6-inch, and fourteen rapid fire guns; the *Benbow*, two 110-ton, ten 6-inch, and fifteen rapid fire guns; the *Collingwood*, four 44-ton, six 6-inch, and fifteen rapid fire guns. The I. H. P. and speed are as follows: *Rodney* and *Benbow*, 11,500 and 16.75; *Collingwood*, 9,570 and 16.5.]

Good sea boats; low freeboard renders them unsuitable as sea-going armor-clads for general service, as their speed would be rapidly reduced when steaming against a head wind and sea.

Conqueror, Hero. [Single turret battle-ships. Length b. p., 270; beam, 58; mean draught, 23; displacement, 6,200 tons. Armament: two 12-inch and four 6-inch guns. Vertical, twin-screw, compound engines; I. H. P., 5,800; speed, 15½ knots.]

Roll a great deal; motion easy; handy; steer well, and answer helm quickly; hulls need strengthening in vicinity of thrust bearings.

Mersey, Severn, Thames. [Protected cruisers, with two military masts. Length b. p., 300 feet; beam, 46; mean draught, 19 feet 6 inches; displacement, 4,050 tons. Twin-screw, horizontal, compound engines of 5,700 I. H. P.; speed, 17 knots. Two 8-inch pivots and ten 6-inch guns.]

Good sea boats; handy; steady gun platforms; 8-inch guns on poop and forecastle should be replaced by lighter ones.

Arethusa. [Protected cruiser, barkentine rigged. Length b. p., 300; beam, 46; mean draught, 20½; displacement, 4,300 tons. Twin-screw, horizontal, compound engines; I. H. P., 4,666; speed, 16 knots. Armament: ten 6-inch guns, besides machine guns and torpedoes.]

Good sea boat; steams well against a moderate head sea and strong wind; rolls heavily with sea abeam or aft, hence unsteady as a gun platform; quick and heavy rolling makes accurate shooting an impossibility and machine guns in the tops useless. Improvements suggested: remove square rig on foremast; remove fighting tops; enlarge rudder; reduce weight of battery.

Archer, Cossack, Mohawk, Tartar, Raccoon, Serpent. [Gunboats with light protective decks, barkentine rig. Length b. p. 225, beam 36, mean draught 14 feet 3½ inches, displacement, 1,770 tons. Armament, six 6-inch and eight rapid fire guns. Twin-screw, horizontal, compound engines of 3,500 I. H. P.; speed, 17 knots. The *Racoon* and *Serpent* have two feet more beam than the others, and the same displacement on a draught of 13 feet 6 inches. The I. H. P. is 4,500 and the speed 17.5 to 18 knots. These are the official figures for these ships, but the speeds recorded are about half a knot in excess of what they really do.

The *Yorktown* is of the same dimensions as the *Archer.*]

Good sea boats, but crank; pitch heavily on account of heavy weight in the bows; speed much reduced in a head sea; quick rollers, and therefore unsteady gun platforms; handy; battery too heavy; weights on forecastle too great, and forecastle itself not strong enough for the weight it has to bear. The *Racoon*, going 10 or 11 knots against a moderate swell, shipped a sea which carried away everything movable on the forecastle, broke in the fore-hatch, which was battened down, tore away the iron stanchions supporting the forecastle, and bent the beams down three inches. Improvements suggested: stow bower anchors farther aft; remove sheet anchor to a position near main mast; substitute 5-inch for 6-inch guns on the forecastle. It is also suggested to substitute 5-inch guns throughout.

[These observations are fully confirmed by reports from the *Porpoise*, a sister vessel, on the China station. It is stated that she buries herself forward, and if driven hard "displays a tendency to shake herself to pieces."]

Rattlesnake, Sandfly, Spider, Grasshopper. [Torpedo gunboats 200 feet long, and 20 feet beam. They were originally designed to draw 8 feet of water and to displace 450 tons. After the *Rat-*

tlesnake was completed, it was found that her draught was 9 feet and her displacement 550 tons. Her speed is 18.5 knots and I. H. P., 2,700. The others, which have not yet completed their steam trials, are expected to make 19 knots with 3,000 I. H. P. on a draught of 8 feet 9 inches, and a displacement of 525 tons.]

Satisfactory sea boats, and, *provided they are handled with care*, safe vessels; extremely lively and ship a great deal of water except when steaming *easy* against the sea, or running full speed before it; difficult to keep on course; unsteady as a gun platform except in a calm; 4-inch gun could not be fought in a sea-way; do not answer the helm quickly. Improvements suggested: remove the 4-inch gun; strengthen the hull throughout; raise the freeboard; "turtle-back" the forecastle.

The hulls of these vessels have been strengthend during the past year, and the *Sandfly*, *Spider* and *Grasshopper*, which, at the time of the manœuvres, had not had a satisfactory contractor's trial with forced draft, have recently had unsatisfactory trials. The *Sharpshooter* class, similar but larger vessels, have been similarly strengthened.

Under the head of "defects of importance" to the machinery, are found the following:

Rodney.—Glands required repacking.

Benbow.—Air compressing machinery for Whitehand torpedoes inefficient and insufficient for its work.

Warspite.—Crowns of furnaces came down.

Northampton.—Steam stearing gear continually giving out, rendering ship unmanageable. Steam capstan invariably breaks down while weighing.

Severn.—Cover of air-pump defective.

Mersey.—Leaky tube ends. Tubes leaky and salted. Boilers disabled at varying times from 35 to 66 hours.

Serpent.—Valves and steam pipes leaking.

Mohawk.—Boiler tubes choked and leaking; fitted with Weir's evaporators, which primed, supplying salt instead of fresh water to boilers.

Grasshopper.—Exhaust pipe of main feed donkey broken at flange, due to excessive vibration; vessel to be strengthened by a system of struts and brackets.

Torpedo-boats.—Fresh water arrangements very unsatisfactory.

Although these are all that are given under the head of "defects of importance", in the record of the proceedings of each squadron it is stated that the *Mercury*, on the 8th of August,

went to Holyhead for repairs; and again that the *Racoon* was ordered to Davenport to repair steam pipe. From another source, it is learned that her main steam pipe burst, necessitating the hauling of fires from two boilers. After repairs were completed, when asked what speed she could make and for how long, replied "Thirteen knots for four or five days".

On the 10th of August, the *Sandfly*, which was only cruising during the daytime off Queenstown, carried away her starboard high-pressure link, and on another occasion the air-pump of the port engine was "disabled", and she had to steam back to port under one engine, making about seven knots.

Regarding some of the captures which were claimed to have been made, the following are of interest, as well as amusing:

The *Volage*, which was cruising on the path of the steamers plying between the British Islands and America, claimed to have captured a large number of steamers, amongst others the *Gallia* and *Servia*, whose ocean speeds are about 15 and 17 knots respectively. The committee says "It is most improbable that the ship (*Volage*), whose 'full speed at sea' is given as 13.5 knots, could have effected the capture of these vessels. * * * It may be observed that the highest speed which was attained by the *Volage* during the manœuvres was 11 knots".

The *Sandfly* claimed to have captured "twenty-three steamers, many of them large Atlantic liners. * * * Her reputed full speed is 19 knots, but by the official list she is only capable of keeping up 15 knots at sea". One of the steamers claimed was the *City of Rome*, but the captain of that steamer indignantly denied that the *Sandfly* overtook his ship, and says that the *Rome*, going 17 knots, dropped her at the rate of a knot an hour.

There seems to have been a general want of more firemen in all the ships, and especially of thoroughly trained ones for working under forced draft. The committee points to the fact that when the *Warspite* broke the blockade, going 16 knots, "thirty-six deck hands were sent to assist in the stokehold at a time when, in real war, every man would be required at his station for battle." They recommend that newly-raised stokers serve at least one year as supernumerary in a seagoing ship before they are considered fit to be drafted as part complement to any vessel.

CASUALTIES AND REPAIRS.

[It is the purpose of the Council to illustrate under this head the practical methods adopted on board ship for doing such work as would ordinarily have to be done in a shop, or ingenious methods which have been devised for doing such work as that described below. In sending in such items, sketches should be made on plain white paper, and rolled, not folded.]

The following is contributed by Assistant Engineer S. H. Leonard, U. S. Navy:

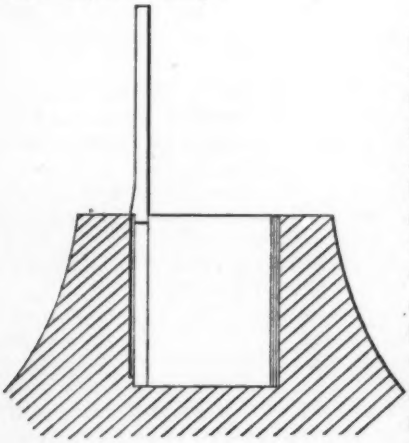


Fig. 1.

In November, 1885, it became necessary to fit new crank-shaft brasses to the U. S. Fish Commission steamer *Fish Hawk*. With the facilities in the way of tools offered at the Wood's Holl Station the work was performed by the engineer's force on board. The old brasses were cast with projecting ribs, or chipping strips, and upon removing them it was found that the pillow-block faces were badly scored. To true up these faces with hammer, chisel and file with any degree of accuracy, was proving a long and tedious job, and as the vessel was needed in January, time became a factor of importance. Finding an old cast-iron safety-valve weight of rectangular section which would fit between the jaws of the pillow-blocks, it was faced, and a tool made of 1 x ¾ inch steel about 10 inches long, and

Fig. 2.

with a cutting lip at its end, as shown in Fig. 2. Several $\frac{1}{32}$ inch shims to fit between the weight and jaws completed a crude slotting machine.

Properly adjusting the shims, the tool was driven between the weight and jaw, as shown in Fig. 1, with but little effort, leaving a comparatively smooth and true surface; the small shoulder left at the bottom of the jaw was trimmed off with a chisel.

In this manner the remaining seven faces of the jaws were finished more accurately and in much less time than had been spent on the first face with chisel and file.

SHIPS.

UNITED STATES.—*Maine.* The contract for building the machinery of this vessel on the design of the Bureau of Steam Engineering has been awarded N. F. Palmer, Jr., & Co. (Quintard Iron Works), New York, for the sum of $735,000.

The *Maine* is a twin-screw, armored turret vessel, and in general appearances resembles the Brazilian armored cruiser *Riachnelo*, having a central superstructure between the two turrets, which are placed *en echelon*, as in the *Atlanta;* but unlike the latter vessel, has a poop and topgallant forecastle. She is bark rigged, and the fore and main masts are fitted with military tops. Her general dimensions are: length between perpendiculars, 310 feet; breadth, extreme, 57 feet; mean draught, 21½ feet; displacement, 6,648 tons; area of midship section, 1,080 square feet; area load water plane, 13,576; I. H. P., 9,000; speed, 17 knots.

The main battery consists of four 10-inch and six 6-inch rifles, and the secondary of twenty-five machine guns. The 10-inch guns are placed in the turrets; two of the 6-inch guns are forward, two aft, and one on either side of the central superstructure, all protected by 2-inch shields. The thickness of turret armor is 10½ inches, and that of the armor belt (which extends for a distance of 180 feet amidships, three feet above and four feet below the water line), 11 to 12 inches above and 12 to 6 inches below water. The wood backing is 8 inches thick. From the top of the armor belt, at its after end, the armored deck slopes to the under water deck. The thickness of armor on the slope is 4 inches and of the under water deck 2 inches. There are seven torpedo tubes, three below water and four on berth deck.

The engines are of the vertical, inverted-cylinder, direct-acting triple-expansion type, with cylinders 35½, 57 and 88 inches diameter by 36 inches stroke, designed for 9,000 I. H. P., with a piston speed of about 800 feet per minute. All cylinders are steam jacketed, and all the piston valves (one for the H. P., two for the I. P. and three for the L. P. cylinders,) interchangeable, and work by Stephenson double-bar link-motion. The engine framing consists of hollow cast-steel columns, trussed by wrought-iron stays. The shafting is hollow, and the crank-shafts made in interchangeable sections, the cranks being placed at 120° with each other. The condensers are cylindrical, made entirely of composition and sheet brass, and each contain about 7,010 square feet of cooling surface. The air pumps are horizontal, double-acting, and worked by compound engines.

The circulating pumps are of the centrifugal type, driven by inclosed three-cylinder engines. The screw propellers are three-bladed, and made of manganese bronze.

There are eight single ended, horizontal return tubular boilers, each 14 feet 8 inches in diameter and 10 feet long, working at a pressure of 135 pounds per square inch. They are placed in two water-tight compartments with fore and aft fire-rooms. There are three furnaces in each boiler, each 42 inches in diameter, the total grate surface being 553, and the heating surface 18,800 square feet. The forced draft is on the closed ashpit system.

The H. P. cylinder of each engine is placed aft, and exhaust pipes are provided from the I. P. cylinder to the condenser, so that the engine may be run as a compound engine at low power, the design being for economy at full power when working as a triple-expansion engine. The weight of machinery is 890 tons. The time fixed for the completion of the machinery and its delivery at the navy-yard, New York, is two years and six months from date of contract, and that for its final erection and completion on board, three years and six months.

Coast Defense Vessel. The bids for the construction of this ship were opened on the 3d of April, the William Cramp & Sons Shipbuilding Co., of Philadelphia, being the lowest bidder, $1,614,000. This bid was on the Department's design, with certain modifications in the machinery, but did not guarantee the horse-power. The contract was accordingly awarded the Union Iron Works, San Francisco, on the Department's design throughout, for $1,628,950.

She is a low, free-board, twin-screw vessel of the monitor type, with a military mast, and of the following dimensions: length between perpendiculars, 250 feet; breadth, extreme, 59 feet;

mean draft, 14½ feet; displacement, 4,000. There is an armor belt extending the entire length of the vessel, 16 inches thick along the vital parts, and 8 and 6 inches at the ends. An armored deck 3 inches thick is fitted over the machinery and magazines, tapering to 2 inches at ends.

The battery consists of one 16-inch (110-ton) gun in the forward barbette; one 12-inch (46-ton) gun in the after barbette; one 15-inch dynamite gun, and 15 rapid fire guns.

The engines are of the same general type as those of the *Maine*, except that the cylinders are not steam jacketed, and the H. P. cylinder only is provided with a working liner. The cylinders are 27, 41 and 64 inches in diameter, by 30 inches stroke, designed for 5,400 I. H. P. The piston valves for the H. P. and L. P. cylinders are interchangeable. The cylinders are supported on inverted Y cast-steel frames. The condensing surface is 7,696 square feet.

The principal feature about the machinery is the boilers. The specifications provide that 1,200 I. H. P. will be furnished from cylindrical return tubular boilers, and the remainder (4,200) from "coil", "sectional", or "tubulous" boilers, all constructed for a working pressure of 160 pounds per square inch.

The type of "coil" boiler has not yet been determined, but the boilers which will probably be tested are the Cowles, the Ward, the King, and the Hohenstein.

Texas. The bids for the construction of the machinery of this ship were opened May first, the lowest bidders being the Richmond Locomotive and Machine Works, Richmond, Va., and the sum $634,500.

The *Texas* is a twin-screw, armored battle-ship, with a belt of armor arranged similarly to that of the *Maine*. She carries no sail, but has two military masts.

Her principal dimensions are: length between perpendiculars, 290 feet; breadth, extreme, 64 feet 1 inch; mean draught, 22½ feet; displacement, 6,300 tons; the I. H. P. is 8,600, and the speed expected, 17 knots.

The armor belt, which is 12 inches thick, with 6 inches of wood backing, protects the magazines and the engines and boilers, and extends 2 feet above and 4½ feet below the water line. The protective deck, which is worked over the armor belt, is 3 inches thick throughout.

The main battery consists of two 12-inch and six 6-inch guns, and the secondary battery of twenty-four rapid fire and machine guns. The 12-inch guns are in two turrets, disposed similarly to, but not so far outboard as those in the *Maine*. One of the

6-inch guns is placed forward and one aft, amidships, on the same level as the turret guns, and the others are mounted in sponsons on the main deck. There are six torpedo tubes, one through the bow, one through the stern, two through the side aft above water, and two through the side forward below water.

The machinery was designed by Mr. A. D. Bryce-Douglas, of the Naval Construction and Armaments Co., Barrow-in-Furness, England, which company also designed the ship.

They are of the same type as the engines of the *Maine*, with cylinders 36, 52 and 78 inches diameter by 39 inches stroke, designed for 8,600 I. H. P., with a piston speed of 800 feet per minute. As in the *Maine*, all cylinders are steam jacketed. The framing is similar to that of the *Coast Defense Vessel*. The condensing surface is 12,924 square feet. Steam is supplied by five double ended return tubular boilers, 14 feet diameter and 18 feet long, designed for a working pressure of 150 pounds per square inch. Each boiler has three 39-inch furnaces. The total heating surface is 16,912, and the grate surface 532 square feet.

The forced draft will be on the closed stokehold system. The weight of machinery given by the designer is 816 tons.

The time fixed for the completion of the machinery is the same as for that of the *Maine*.

ENGLAND.—*Medusa*. (Sister ship to the *Medea*, described on p. 87, of No. 1.) She had her twelve hours' natural draft trial March 5, with the following mean results: steam pressure, 152.5; vacuum, 27.8; revolutions, starboard, 129.9; port, 130.5; I. H. P., 6,334; speed, 18.005. One-half inch air pressure in fire-room.

The forced draft trial took place March 13, with the following results: steam pressure, 149; air pressure, 1.9 inches; vacuum, 26.5 starboard and 26.6 port; revolutions, 143.6 starboard and 143 port; I. H. P., 9,435. No speed was given, so that it is only fair to suppose that, like the *Medea*, she failed to get the 20 knots for which she was designed.

Magicienne. (One of the sheathed vessels of the *Medea* class.) Length, 265; beam, 42; draught, 17 feet 6 inches; displacement, 2,960 tons.

The engines of this ship are of the horizontal, triple-expansion type; cylinders, 34½, 51 and 76½ by 36 inches stroke; four cylindrical, double ended boilers; grate surface, 456 square feet; heating surface, 14,070; condensing surface, 11,850; steam pressure, 155; I. H. P., 5,500 and 9,000, with natural and forced draft respectively.

The first trial under natural draft was made March 8, but was unsuccessful after five hours' steaming, it having been found im-

possible to keep up the steam pressure. The failure is attributed to the fact that the boilers are made with one back connection common to all the furnaces, and that the draft, when a door was opened, would blow flame out the opposite door. Bridges were built in the back connections to remedy this, and she went out again a few days afterwards. This time the results were better, but she failed to get the I. H. P. required, the mean for the trial being 5401, with ½-inch air pressure in the fire-room and 123 revolutions of the engines. She would probably have done better but for a leaky feed pipe during seven hours, necessitating a partial supply of sea water to make up the loss. Speed, 17 knots.

The forced draft trial took place March 23, and was a failure, owing, it is said, to narrow steam ports. The I. H. P. was only 7,500, and the speed 18 knots.

She had another trial, on the 17th of April, but was again unsuccessful, the maximum I. H. P. being 8,400 instead of 9,000. Two of the fire-room fans broke down, and she had to return to port without completing the four hours' run.

Spider. This vessel, of the torpedo gun-boat class, was commissioned last summer for the naval manœuvres before the completion of her machinery trials. Since then she has been undergoing alterations and repairs. Length, 200 feet; beam, 23 feet; draught, 8 feet 9 inches; displacement, 525 tons.

She had a contractor's trial under forced draft on the first of March, on a mean draught of 8 feet 8 inches, with the following results: steam pressure in boilers, 132 pounds; mean pressure in cylinders, 55.8, 30 and 11.3 starboard, and 54, 28.6 and 12.5 port; vacuum, 26.5 and 26.7; revolutions, 305; I. H. P., 415 + 477 + 433 = 1325 starboard, and 400 + 450 + 476 = 1326 port, total, 2651. The contract being for 3,000 I. H. P., the trial was unsatisfactory. The mean of four runs on the measured mile gave a speed of 19.2 knots. The engines are vertical triple-expansion, designed for a boiler pressure of 150 pounds; cylinders, 18½, 27 and 42 inches diameter by 18 inches stroke. The boilers are of the modified locomotive type, having a water bottom under the ashpit.

The *Sandfly*, a sister ship, which also took part in the manœuvres, had an unsuccessful trial on the 12th of March.

On the 11th of April, she had a three hours' successful trial, making 19.2 knots. A few days afterward, she had a trial to determine the coal consumption and the quantity of water wasted. This trial was made at a speed of 11¾ knots, the engines making 180 revolutions; the I. H. P. was about 600, the coal per I. H. P., 2.64 pounds, and the waste of water during the six hours' run, one ton.

Australia. A belted cruiser, sister ship to the *Orlando*, described on page 92 of No. 1, had her commissioning trial on the 17th of April, the mean speed for six hours being 17 knots. She had previously had an unsuccessful trial. On her contractor's trial, the speed for four hours was 18.8 knots.

FRANCE.—It is reported that the *Amiral Cècille* and the *Forbin* have completed their steam trials, the former realizing 20 and the latter 19.8 knots.

The *Cècille* is a protected cruiser of the following dimensions: Length, 379 feet; beam, 49 feet 2 inches; mean draught, 19 feet 8 inches; displacement, 5,766 tons.

The *Forbin* is a smaller vessel, her dimensions being 311½ by 30½ by 14 feet, and displacement, 1,848 tons.

ITALY.—The *Piemonte*, a vessel built by Armstrong, Mitchell & Co., and sold to the Italian government, has for some time been eagerly watched by naval powers, owing to the remarkable speed expected of her, as stated last year by Lord Armstrong. Mr. P. Watts recently read a paper descriptive of the vessel before the Institution of Naval Architects, from which the following data are taken:

Length between perpendiculars,	300 feet.
Beam,	38 "
Mean draught,	15 "
Displacement,	2,500 tons.
Weight of hull and fittings,	970 "
" protective deck,	280 "
" equipment,	130 "
" machinery and spare parts,	720 "
" coal,	200 "
" armament,	200 "

The protective deck is one inch thick in the midde and three inches on the slope, and extends the entire length of the ship. Although the coal given above is 200 tons, she can carry 600, much of which has to be either in bags or in the shape of patent fuel. The after deadwood is cut away, and she is fitted with a balanced rudder, forward of which the deadwood is cut away. She is the first vessel to be armed with quick-firing guns of large calibre, her battery consisting of six 6-inch and six 4¾-inch, besides ten 6-pdr. Hotchkiss and four 10-mm. Maxim guns, and three torpedo guns or tubes.

The engines and boilers are entirely below water, but there is no double bottom in the boiler compartments, and the inner

bottom in the wake of the cranks is cut away so as to permit them to turn.

The engines, designed by Messrs. Humphrys & Tennant, are vertical, twin-screw, triple-expansion, each in a separate water-tight compartment, each engine having two low-pressure cylinders. The cylinders are 36, 55 and 60 inches diameter by 27 inches stroke. There are four double ended boilers, in two water-tight compartments, designed for a working pressure of 155 pounds, besides an auxiliary boiler on the protective deck. An evaporator is fitted for supplying the boilers with fresh water, and there is an auxiliary condenser in each engine-room.

Mr. Watts states that she made 19½ knots on the mile with natural draft; 20.168 on 7.760 I. H. P., with an air pressure of ¼ inch of water; and 20.3 on 8,000 I. H. P. and ½ inch pressure in fire-rooms. The forced draft trials have not been completed, but two runs on the mile are said to have shown over 21 knots and 11,600 I. H. P.

Mr. Watts' paper contains the following significant sentence: Forced draft with high pressure in the stokehold—and anything above two inches should, I think, be regarded as high—can only be reckoned upon for a spurt of three or four hours, and after such a spurt you will usually find that your boilers require some overhauling.

TORPEDO BOATS.

Last summer, the Spanish government carried out a series of exhaustive experiments with some of their first-class torpedo-boats, one of the most important being a competitive speed trial from Carthagena to Alicante, a distance of 68 nautical miles. The conditions of trial were identical with those under which the boats were tried prior to acceptance from the builders, but the results were quite different, the boats arriving in the following order:

	Speed.	*Original speed.*	*Builder.*
Barcelo	19.7	19.5	Normand.
Halcon	19.6	23.0	Yarrow.
Rayo	19.5	26.3	Thornycroft.
Ariete	17.2	26.3	Thornycroft.
Ordoñez	16.1	20.2	Thornycroft.
Acebedo	15.8	20.2	Thornycroft.

The following are the principal dimensions of the boats and the I. H. P. developed on the contractor's trial:

	Length.	*Beam.*	*Mean load draught.*	*Load displacement.*	*I. H. P.*
Barcelo	127′–1½″	11′–0″	.....	65.	.....
Halcon	135 –0	13 –9	3′–11″	100.	1450
Rayo	147 –6	14 –6	4 –6	125.	1626
Ariete	147 –6	14 –6	4 –6	125.	1626
Ordoñez	117 –0	12 –6	3 –5	65.8	666
Acebedo	117 –0	12 –6	3 –5	65.8	666

The displacement of the *Halcon* on trial was about 85 tons, that of the *Rayo* and *Ariete* 99 tons, and of the others correspondingly less.

One of the *Ariete's* boilers was disabled, and she had to make the run under one-half boiler power. Great interest attaches to this trial, from the fact that the *Rayo* and *Ariete* each have Thornycroft's new tubulous boiler. The failure of one of them on the *Ariete*, and the poor speed made by both boats, have been the subject of much discussion. Mr. Thornycroft maintains that the poor speed shown by his boats was due to inexperienced firemen, and that this is especially so in the case of the *Rayo*, which boat, assuming that her firemen were as good as those of the *Ariete*, should have developed 1,060 horse-power and made 22 knots instead of 19.5. But this is based solely on the measured mile performance of the boats, and goes to show that, however valuable such results are, they are valueless for determining the speed of boats under the actual conditions of service. As to the accident to the *Ariete's* boiler, Mr. Thornycroft attributes it, after examination of the boiler, to carelessness on the part of those in charge of it, and to a leaky tube.

It may be stated that the boiler consists of a central horizontal steam drum and separator above the furnace and protected from the direct heat of it, connecting at one end by two pipes with two horizontal drums on either side of the furnace; from these drums a number of bent tubes connect with the separator —these tubes are staggered, and so arranged that the gases of combustion pass between them.

The steam drum is 26 inches in diameter, 10 feet 4 inches long, and .314 inch thick. The pipes connecting it with the lower drums are 8 inches in diameter and 5 feet long. There are 918 bent tubes connecting the drums with the separator; they are in eight rows, and are 1.18 inches in diameter and .11 inch thick. Each boiler has 37.7 square feet of grate, and 2,120 of heating surface, 62 cubic feet of water space, 40 of steam, and occupies 971 cubic feet of space in the boat. On the original trial, each boiler furnished steam at 150 pounds pressure for 813 I. H. P. The weight of the boiler and attachments is 8 tons.

The engines are twin-screw, compound, with cylinders 14½ and 24½ inches diameter by 15 stroke, the barrels and ends of the cylinders being steam jacketed.

The following are the total weights of the machinery of the *Ariete:*

Engines, pipes, etc.,	41,148	pounds.
Boilers, attachments and pipes,	38,526	"
Water in boilers	7,648	"
Condenser,	837	"
Total,	88,159	"

or in round numbers, forty tons.

As an illustration of the reduction of weight due to the use of the tubulous boilers, it may be stated that the weight of a locomotive boiler in the *Habana* is 12 tons, and the I. H. P. 705, while the *Ariete's* boiler weighs 8 tons, and develops 813 I. H. P.

On the first of March a trial was made at Portsmouth, England, of a torpedo-boat built by Messrs. Doxford & Son, the principal feature in which is the employment of creosote instead of coal as the fuel.

The boat is 137 feet long and 13 feet 9 inches beam.

The engines are of the triple-expansion type, the cylinders being 15, 22½ and 33½, by 18 inches stroke. The boiler is of the locomotive type, with a wet-bottom fire-box. No difficulty was experienced in keeping up the steam pressure, the only objection urged against the fuel being its higher cost compared with coal.

It was fed to the furnace under a pressure of 40 pounds, through a number of small jets, similar to the apparatus described in the last report of the Chief of the Bureau of Steam Engineering.

The following data were obtained during a run of two hours: steam, 158.6; vacuum, 23; revolutions, 312; I. H. P., about 900. A mean speed of 19 knots was realized on the mile.

The French are just now experiencing much trouble with some of their torpedo-boats. On the 2d of March No. 102 capsized near Toulon, and shortly afterwards No. 110, of the same design, met a similar fate near Cherbourg. The trouble seems to be in the design of the boats, they being considered unsafe except in perfectly smooth water. Fifty-three of them have been built, their dimensions being—length, 115 feet; beam, 11 feet; draught, under skeg, 6 feet; draught, amidships, about 3 feet 6 inches; displacement, 53.7 tons; area of immersed midship section, 23 square feet. Their speed is 20 knots, and the I. H. P. 525.

ERRATA.

The length and beam of the *Victoria* and *Sanspareil*, given on page 84 of No. 1, should be, respectively, 345 and 73 feet.